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Technical and economic viability of the implementation of approach systems (radio aids) in regional airfields
(Viseu airfield case study)

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Resumo

Apesar de todos os esforços desenvolvidos pelas várias instituições dedicadas à segurança aeronáutica, acidentes e incidentes continuam a ocorrer, independentemente de qualquer circunstância e momento. Cerca de metade desses acidentes, a nível comercial, verificam-se essencialmente durante as fases de aproximação e aterragem. Os sistemas de aproximação foram projetados com o objetivo principal de aumentar os índices de segurança nessas fases do voo, reduzindo os riscos inerentes à sua complexidade. Esses equipamentos podem ser divididos em sistemas de precisão (orientação lateral e vertical fornecida) e de não precisão (somente orientação lateral fornecida).

Quando falamos de transporte aéreo, é difícil não associarmos o tema aos grandes aeroportos distribuídos pelo mundo. Apesar de eles representarem uma parte crucial de toda a indústria aeronáutica, não podemos deixar de relevar os aeroportos e aeródromos regionais, pois estes também alcançam níveis inigualáveis de importância para as pessoas e regiões que representam.

O caso de estudo utilizado foi o aeródromo de Viseu, e para confirmar a sua importância para a região, foram inquiridas as maiores empresas locais. Após 19 respostas, foi possível confirmar a relevância que tem ou poderia ter o aeródromo, tendo sido este a escolha preferencial em comparação com os aeroportos internacionais do Porto e Lisboa.

O principal objetivo deste trabalho foi demonstrar até que ponto a implementação de um desses sistemas de aproximação no aeródromo é viável, e qual seria a melhor opção para este caso quer do ponto de vista técnico quer económico. Os sistemas analisados para este estudo foram o ILS e GBAS, ambos equipamentos de precisão.

Depois de uma análise técnica e económica, relevando as características técnicas do aeródromo, bem como as suas receitas provenientes das taxas cobradas, conciliadas com um projeto financiado em cerca de 80% e com uma previsão de recuperação do investimento em seis anos, concluiu-se que o GBAS seria a opção mais indicada. Posto isto, foram elaboradas cartas de aproximação GLS com base em cartas GNSS já existentes no aeródromo.

Palavras-Chave

Aeródromo regional; Desenvolvimento regional; Rádio-ajudas; Sistemas de aproximação; Segurança

Resumo alargado

Apesar de existir uma preocupação cada vez maior por parte de várias instituições relativamente à segurança aeronáutica, os acidentes e incidentes continuam a ocorrer. Não obstante ocorrerem em situações fora do nosso controlo, muitos podem ser prevenidos ao serem tomadas medidas e ações apropriadas. Cerca de metade destes acidentes, a nível comercial, acontecem durante as fases de aproximação e aterragem. As rádio-ajudas foram concebidas com o intuito de permitir aos pilotos uma maior segurança durante o voo. Dentro destes equipamentos, encontram-se os sistemas de aproximação, que foram planejados com o principal objetivo de aumentar os níveis de segurança nestas fases de aproximação e aterragem, que já em si apresentam vários riscos devido à sua complexidade. Estes sistemas podem ser classificados em sistemas de precisão (onde é fornecida orientação lateral e vertical) e de não-precisão (só orientação lateral). Os principais sistemas de não precisão revistos neste trabalho foram o VOR, GPS e NDB, enquanto que dentro dos sistemas de precisão foram estudados o ILS, MLS, TLS e o PAR. Ainda dentro dos sistemas de precisão, foram também estudados os sistemas de aumento GNSS, entre os quais o ABAS, GBAS e SBAS. Estes sistemas permitem melhorar o sinal fornecido pelo GNSS através de equipamentos instalados nos aeroportos e nas aeronaves.

Os aeroportos têm-se tornado cada vez mais infraestruturas essenciais na economia global, aumentando a competitividade regional, nacional e internacional. Os aeroportos regionais representam um papel bastante importante na indústria da aviação. Apesar de geralmente servirem rotas de curta e média distância, muitos têm a importante função de aliviarem o congestionamento dos maiores aeroportos nas proximidades. Além disto, têm um papel crucial ao prestar serviços essenciais como: assistência médica, educação, resgate ou até mesmo combate a incêndios na própria região. A procura e utilização destes aeroportos e aeródromos regionais tem aumentado significativamente ao longo das últimas décadas (173% de 1993 a 2015). Apesar de em Portugal as cadeias aéreas regionais não serem tão significativas, comparativamente ao cenário mundial, esta evolução também é verificada, apesar de ser em proporções mais reduzidas.

O caso de estudo utilizado neste trabalho foi o aeródromo Gonçalves Lobato, em Viseu. À semelhança de vários aeródromos no país, o aeródromo de Viseu também desempenha um papel fundamental no desenvolvimento da sua região, sendo parte integrante de uma rede regional de transporte aéreo única no país que liga Bragança a Portimão. A existência de unidades de proteção civil e de combate a incêndios, além da recente instalação de uma escola de aviação para formar pilotos de linha aérea comercial são algumas das razões que tornam esta infraestrutura cada vez mais relevante no panorama nacional. Para confirmar esta importância do aeródromo para a região, foram também inquiridas as maiores empresas locais. O principal objetivo deste inquérito foi verificar o posicionamento estratégico do aeródromo de Viseu para substituir (eventualmente) os aeroportos internacionais do Porto e de Lisboa, em termos de transporte de passageiros, para as empresas locais. Após 19 repostas, facilmente se verificou a relevância que o aeródromo tem ou poderia vir a ter para a região, tendo sido este a escolha preferencial em comparação com os aeroportos do Porto e Lisboa. Foi também feita uma breve revisão do arquivo meteorológico de Lordosa, freguesia onde o aeródromo está inserido, na qual se verificou a existência de alguns períodos onde o mau tempo era predominante e que por isso mesmo, o aeródromo beneficiaria da instalação de um novo sistema de precisão, tendo em conta não só a maior segurança fornecida, mas também a redução do número de voos que teriam de ser desviados devido às condições atmosféricas. Após isto, foi feita uma estimativa da área de influência do aeródromo, pois ao contrário dos aeroportos do Porto e de Lisboa, esta área não se encontra especificada pela ANA. Foi então obtido um círculo com raio de 88km com centro no aeródromo, verificando-se que o aeroporto do Porto era o principal concorrente, o que pode ser explicado pela sua proximidade. Foi também efetuada uma análise simples do desenvolvimento da região de Viseu, analisando a evolução da população residente e das empresas ao longo dos anos. Concluiu-se que, apesar da população ter vindo a diminuir, o número de empresas tem vindo a aumentar. Através de um modelo de regressão linear múltiplo, e utilizando as empresas como variável, foram feitas projeções para os movimentos do aeródromo nos próximos 10 anos. Outro método de projeção foi usado, utilizando os valores definidos pela IATA para a esperada evolução de tráfego aéreo no aeródromo e a similaridade foi evidente, sendo esperados quase 15000 movimentos no ano de 2029, o que vem comprovar o aumento de movimentos que o aeródromo tem vindo a apresentar nos últimos anos.

Este trabalho teve como principal objetivo verificar até que ponto a implementação de um dos sistemas de aproximação previamente referidos seria viável, e qual seria a opção que mais beneficiaria o aeródromo, de um ponto de vista técnico e económico.

Posto isto, e após feita uma seleção foram analisados para este estudo o ILS e GBAS, ambos sistemas de precisão. De um ponto de vista técnico, verificou-se que o GBAS traria mais vantagens em comparação ao ILS. Não só por ser mais fácil de instalar, mas também porque apenas uma estação GBAS seria suficiente para suportar várias cabeceiras de pistas, reduzindo o número de sistemas no aeródromo. Um sistema GBAS CAT I também pode ser facilmente atualizado para CAT II/III, o que pode vir a ser bastante útil para o aeródromo em tempos futuros. Apesar do aeródromo não possuir o equipamento necessário para a instalação deste sistema, este pode ser facilmente adquirido. O produto então selecionado para este caso foi o SmartPath GBAS, da Honeywell.

Em termos económicos, o GLS também foi a melhor opção encontrada, apresentando valores de operação e manutenção inferiores em comparação com o ILS. No primeiro ano de operação, este sistema pouparia cerca de 1 067 000€, comparativamente ao ILS e 1 391 000€ num período de 10 anos. Para melhor se analisar a componente económica, foi feito um estudo dos valores das taxas cobradas no aeródromo ao longo dos últimos anos. Utilizando as previsões da IATA e admitindo que 60% dos movimentos no aeródromo pagavam as taxas cobradas (que aumentaram em 15% após a instalação do equipamento), foi obtido um valor de 635 245€ proveniente das taxas (de 2021 a 2029), com o equipamento a ser instalado em 2021. Estas receitas conciliadas com um projeto financiado em cerca de 80% tornaram o GBAS a melhor opção para este caso. Com um custo de equipamento inicial de 694 000€ e custos de operação anuais de 43 000€ foi prevista uma recuperação do investimento em seis anos. Após verificado que este sistema seria o mais apropriado e o que traria mais benefícios para este caso, foram elaboradas cartas de aproximação GLS, tendo por base cartas GNSS já existentes no aeródromo.

Durante o desenvolvimento deste trabalho, vários tópicos foram reconhecidos como úteis e suscetíveis de serem implementados em trabalhos futuros, de forma a se valorizar cada vez mais a segurança e reduzir algumas inconveniências (principalmente devido ao mau tempo) no transporte aéreo. Posto isto, e particularizando o caso do aeródromo de Viseu, os próximos passos deste trabalho devem seguir as seguintes linhas de estudo:

- Inquirir um maior número de empresas, não só na região de Viseu, mas também de regiões vizinhas, obtendo um maior número de respostas;
- Obter uma maior amostra relativamente aos movimentos no aeródromo, visto que ao contrário dos anos anteriores, atualmente os mesmos tendem a aumentar de uma forma sistemática;
- Tentar obter valores exatos da receita das taxas no aeródromo em cada ano, assim como contabilizar outros tipos de taxas além das taxas de aterragem, de modo a obter projeções cada vez mais realistas;
- Analisar e comparar uma maior variedade de sistemas de aproximação, especialmente os que têm surgido mais recentemente;
- Analisar casos de sucesso após a implementação de um sistema deste género em aeródromos semelhantes e verificar o impacto registado, essencialmente ao nível do aumento de movimentos.

Assim, o objetivo primordial será conferir uma maior segurança ao maior número de infraestruturas aeronáuticas possível, sabendo que para cada caso as opções a tomar terão de ser diferentes, tendo em conta as suas limitações técnicas e económicas.

Abstract

Despite all the efforts made by various institutions towards aeronautical safety, accidents and incidents are likely to happen at any time and under any circumstance. Around half of these accidents, at a commercial level, tend to occur during the approach and landing phases. Approach systems were developed with the main objective to improve the safety index in these flight phases, reducing the inherent risks of its complexity. This equipment can be categorised as precision providing course guidance and glidepath and non-precision providing course guidance only.

When we talk about air transportation, it's hard not to associate the theme to the big airports in the world. Despite of them representing a crucial part of all the aeronautical industry, regional airports and airfields can't be ignored, because they also reach unmatchable levels of importance for the people and the regions they represent.

The case study utilised was Viseu airfield, and to confirm its importance for the region, the biggest local companies were inquired. After 19 answers, it was possible to confirm the relevance the airfield has or could have, being the preferential choice compared to the international airports of Oporto and Lisbon.

The main objective of this work was to demonstrate to what extent the implementation of one of those approach systems in the airfield is viable, and which one would be the better option for this case, from a technical and economic view. The systems analysed for this study were ILS and GBAS, both precision equipment.

After a technical and economic analysis, revealing the technical characteristics of the airfield, as well as its revenue from the charged fees, allied with an 80% funded project with a six-year investment recovery forecast, it was concluded that GBAS would be the most suitable option. GLS approach charts were then elaborated, based on already existing GNSS charts in the airfield.

Keywords

Regional airfield; Regional development; Radio aids; Approach systems; Safety

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List of Acronyms

AAIM	Aircraft Autonomous Integrity Monitoring
ABAS	Aircraft Based Augmentation System
A-SMGCS	Advanced Surface Movement Guidance and Control System
ATC	Air Traffic Control
CAB	Cabeceira da Pista
CBA	Cost-Benefit Analysis
CFIT	Controlled Flight into Terrain
DH	Decision Height
DME	Distance Measurement Equipment
ECAC	European Civil Airspace Conference
EGNOS	European Global Navigation Satellite
FAF	Final Approach Fix
GBAS	Ground-Based Augmentation System
GDP	Gross Domestic Product
GLS	GBAS Landing System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
IAF	Initial Approach Fix
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Instrument Landing System
INE	Instituto Nacional de Estatística
INEM	Instituto Nacional de Emergência Médica
LF	Low Frequency
LOC	Loss of Control
MAP	Missed Approach Point
MDA	Minimum Descent Altitude
MDH	Minimum Descent Height
MF	Medium Frequency
MLS	Microwave Landing System
NAV	Navegação Aérea de Portugal
NDB	Non-Directional Beacon
PAR	Precision Approach Radar
PBN	Performance-Based Navigation
RAIM	Receiver Autonomous Integrity Monitoring

RNP	Required Navigation Performance
RNP AR	Required Navigation Performance Authorization Required
RVR	Runway Visual Range
SBAS	Satellite-Based Augmentation System
TACAN	Tactical Air Navigation
TELOS	Technical Economic Legal Operational Schedule
TLS	Transponder Landing System
VDB	VHF Data Broadcast
VFR	Visual Flight Rules
VHF	Very High Frequency
VOR	VHF Omni-directional Range
WAAS	Wide Area Augmentation System
WATF	World Airport Traffic Forecasts

Chapter 1 - Introduction

1.1. Motivation

Regardless of being a growing concern relative to aeronautical safety, accidents and incidents are still a constant. Even though some of them happen in situations beyond our control, others can be prevented by taking appropriate action and measures.

Due not only to the importance of this subject in the aviation industry but also to the interest it arises, mainly as a way of improving these safety indices and to a better knowledge of its operation principles, we have decided to develop a work focused in radio aids, more specifically in approach systems, since it is during this flight phase, along with landing, that the greatest number of accidents occur, especially at a commercial level, as shown in figure 1.1.

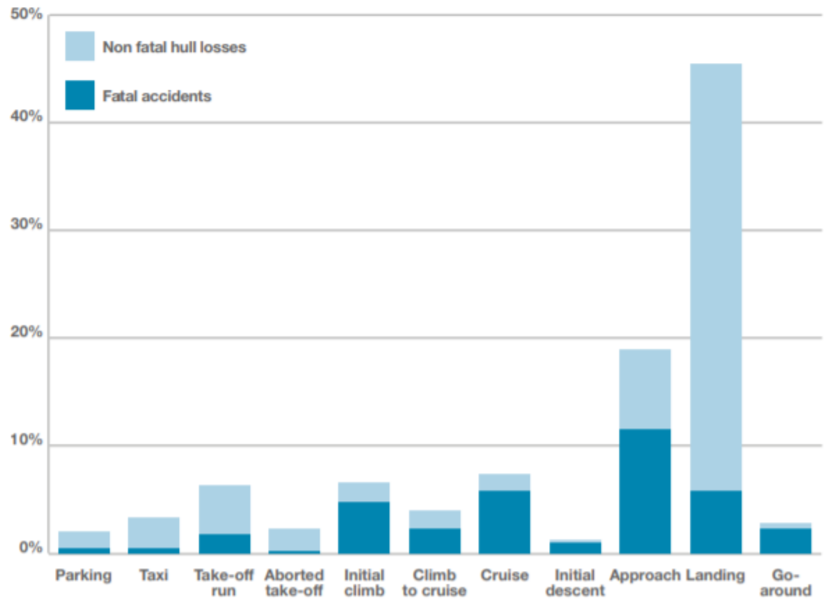


Figure 1.1. Accidents by flight phase as a percentage of all accidents (1998-2017) [1]

These percentages highlight the complexity of these phases with high crew workload, which can be further aggravated by disadvantageous weather or traffic conditions [1].

In addition to these reasons, we have also found engaging to understand to what extent the cost of a certain infrastructure used to improve these same safety indices, allows this implementation to be possible and viable, not only theoretically but also in its practical terms, considering all the limitations which surround the case study.

In this project, we are going to study the case of Viseu airfield, that just like most airfields is a significant asset to its region, promoting its development, as in social as in economic terms, which can be confirmed by observing its traffic evolution that has been a constant since 2014, as the figure 1.2 illustrates.

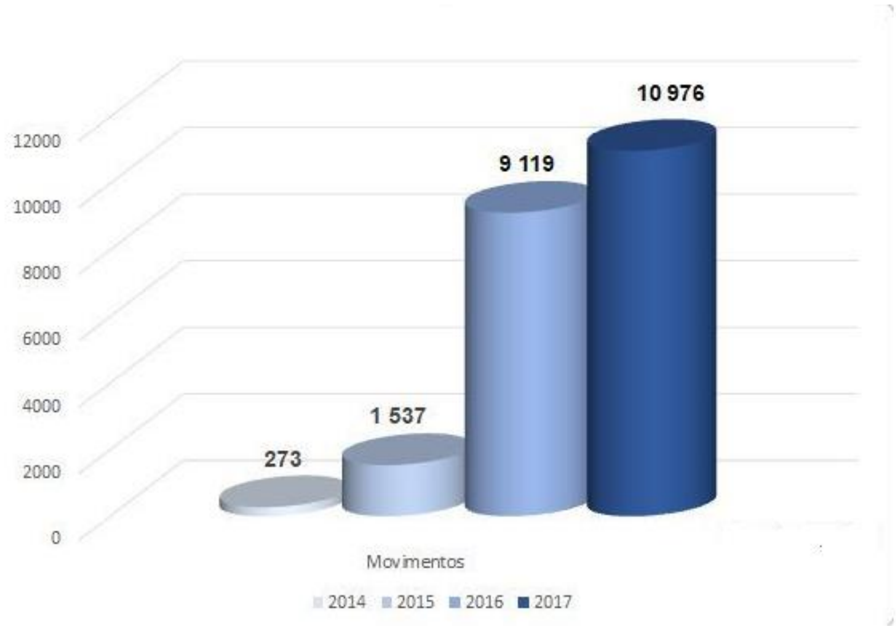


Figure 1.2. Viseu airfield traffic evolution (movements) in the past years [2]

Saying all this, the interest arises in analysing the cost/benefit ratio of these types of infrastructures, that is, radio aids, applied in the airfield, leading to conclusions of whether it justifies or not the installation or replacement of a specific approach system. If it does justify, it would be interesting to see how many years the project would need to reach the break-even point (when the profits equal the costs). Despite now utilizing GPS approach procedures (a non-precision system which uses lateral but not precise vertical guidance), a possible swap for another type of approach system, especially a precision one, if done in a sustainable budget, would bring several advantages, having as a target the improvement of the safety level.

1.2. Object and objectives

This work will have as the object of study Viseu aerodrome, Gonçalves Lobato, with the following objectives:

- Analysing and studying the different existing radio aids, more specifically precision and non-precision approach systems, as a way to improve safety levels;
- Exposing the impact of this infrastructure as a driver for the airfield development and demand growth, given its evolution throughout the years;

- Understanding in which conditions and to what extent the implementation or replacement of a given approach system is viable, balancing its strengths and weaknesses by performing feasibility studies;
- Analysing the results and verifying the impact this decision would have not only in the airfield but also within its region, both in the social but especially economic fields.

1.3. Keywords

Regional airfield; Regional development; Radio aids; Approach systems; Safety

1.4. Methodology

The methodology used in this dissertation will include a literature review on regional airfields, as well as on radio aids, more specifically on approach systems, both precision, and non-precision types. The case study will be Viseu airfield and for the experimental part, besides contacting both aerodrome's authorities and local economic agents, inquiries will be needed to gather the required information to perform technical and economic studies to evaluate the system's feasibility and the impact it would have in the airfield and in its catchment area. The results will then be verified and certified with the corresponding authorities, leading to new conclusions and possible political measures. An arrangement of the methodology can be found in figure 1.3.

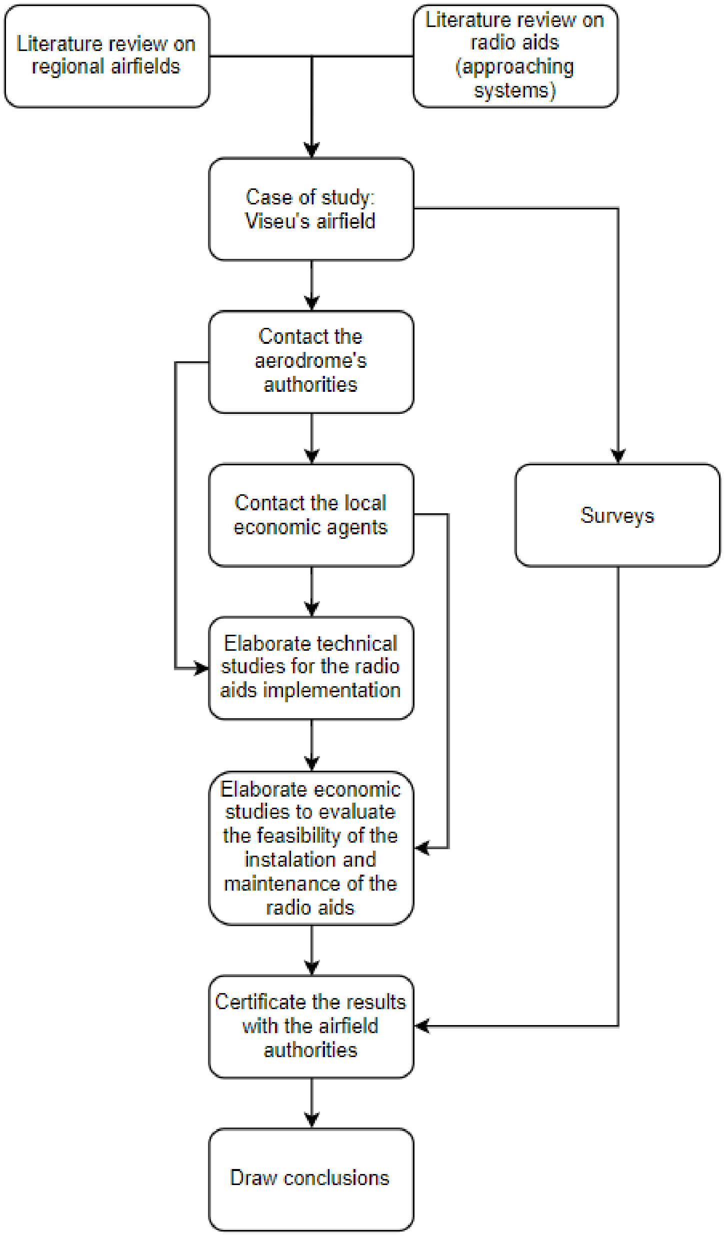


Figure 1.3. Work methodology

With the methodology now illustrated, the different topics can be assembled in five chapters, structuring this work as shown in the next section.

1.5. Structure of the dissertation

This dissertation is composed of five chapters: Introduction, State of the art, Case study, Results analysis, and Conclusion. The first chapter is divided into four topics: motivation, object and objectives, methodology and structures. The second chapter includes an introduction to regional airfields, their economic impact and, the concept of catchment areas. Following this, we have the theme of radio aids, specified into the different approach systems, both precision, and non-precision. After these, the thematic of technical and economic feasibility was introduced, finishing the chapter with a conclusion.

The third chapter is similar to the second, with the variant of all the steps previously described being applied to Viseu airfield (the case study). There's also presented a brief analysis of the meteorological archive of the region where the airfield is inserted.

In the fourth chapter, the results and data from the previous chapter were reviewed and analysed. It is formed by an analysis of the region of Viseu, the economic impact of its airfield (mostly from surveys) and technical/economic feasibility studies of the two systems considered, followed by the elaboration of approach charts.

Finally, in the last chapter, there is a synthesis of the dissertation, its final considerations and the perspectives for future research.

After tracing both the methodology and the dissertation’s structure, we can link its corresponding components and obtain the diagram of figure 1.4, arranging the methodology throughout the chapters.

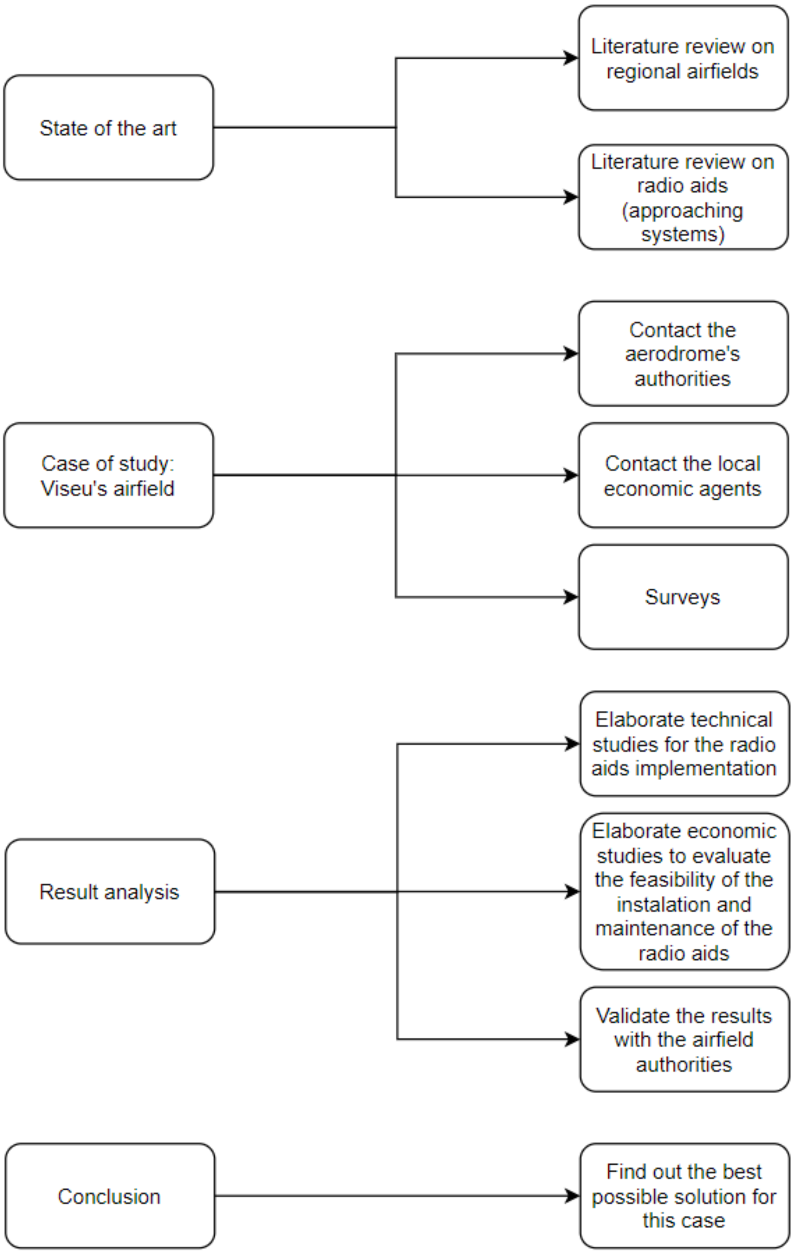


Figure 1.4. Work methodology vs thesis structure

As can be seen, the first chapter of this dissertation isn’t listed above. This is explained by being a more subjective approach to this theme and as the name says, an “introduction” to this work, based around the concept of identifying a problem and trying to work out which measures and decisions can be done to solve it. These measures are described in the following chapters.

Chapter 2 - State of the art

2.1. Introduction

Aeronautical accidents predominantly occur in the final phase of approach and landing (accounting for over 50 percent of all cases at every level of aviation [3]). The most common types of accidents during this phase of flight are CFIT, LOC and runway excursions [3]. Those accidents can happen anywhere between big and busy airports to the smaller, regional ones.

Airports have become crucial functional nodes in the global economy and an extra reason for regional, national, and international competitiveness. "They are growth nodes for local areas and regional economies"[1], having hatch new urban forms, as their impacts (direct and indirect) spillover airport boundaries.

Regional airfields take a very important role in the aviation industry. Despite primarily serving short and medium-range routes, as well as point-to-point destinations, they're also essential when it comes to working as transport nodes, facilitating the connection of people, products, and services [4].

Not only these airfields are essential at offering an alternative to air travel to the population allocated a considerable distance away from a big airport but some of them also take a crucial part in providing essential services such as medical assistance, education, rescuing or even firefighting services for its own region. Taking into consideration its usually not so expensive traveling and parking costs, they're becoming more and more an option not only for business people who wish to travel in a faster and comfortable way but also for tourists who seek a good traveling alternative to visit a given city or region.

These aspects, all combined, are what makes this kind of airfields so important, especially at connecting different regions of a country. Not only they're providing a faster way of transportation for the people who seek it, but in a certain way, they're also helping to feed the bigger airports, working as intermediates in the whole process and making these transitions feel a lot smoother compared to longer travel times and inconveniences that often happen inland transportation.

As we can see in figure 2.1, the search for regional airports has been significantly increasing over the last few decades.

[1] R. Freestone, "Planning, Sustainability, and Airport-Led Urban Development," International Planning Studies. pp. 161

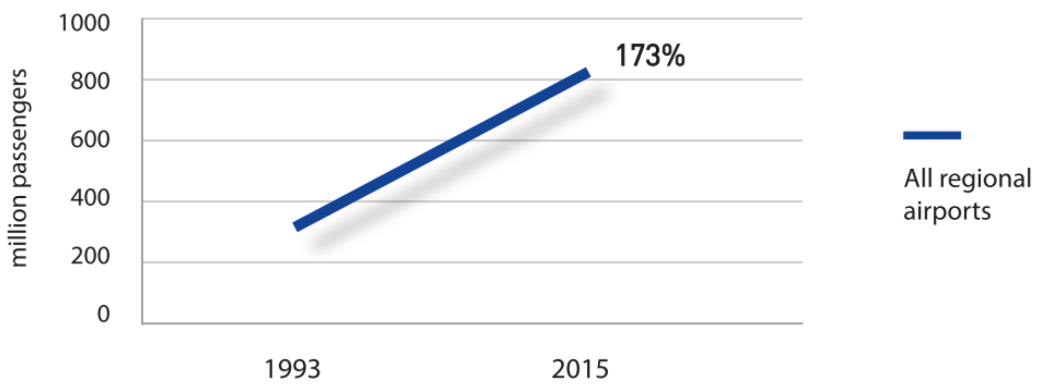


Figure 2.1. Regional airports passengers growth in the last decades [5]

By 2017, global traffic surpassed the 8.2 billion mark and WATF studies expect this number to double by 2034, based on a projected growth rate of 4,3% per year [6]. For countries like Portugal, regional air transportation isn't so significant compared to the global scene, however, this continuous growth is still verified in the last few decades, even though at very lower proportions.

One of the most important factors regarding an airfield's sustained growth is its catchment area. This can be defined as the area nearby the airfield from which passengers feel attracted to use its services. This area can vary due to many aspects such as the airfield's accessibility (geographical location), the expensiveness of its services, capacity, flight frequency or even its proximity to a competing airport [7]. These areas are far from being static, which can be explained by the continuous changes that keep occurring both in the airfield itself or even in the surrounding airports (changes on the flight's schedules, fares and the services they offer).

As has been stated before, infrastructures like the airfields are a critical factor for the growth and development of regions, considering the importance they have in linking these different areas. The association between these infrastructures and regional development is inevitable, and we can distinguish four main types of economic impacts that airfields produce on their regions [8]:

- Direct impacts - employment and income generated by the construction and operation of the airfield;
- Indirect impacts – employment and income generated by a group of suppliers of equipment and services;
- Induced impacts – when the income from employees produced by the previous two types is spent;
- Catalytic impacts – the employment and income generated by the airfield at helping the region's development and attracting new companies.

The catalytic economic impacts from an airport are a very big and important portion of all the impacts these infrastructures can produce. Inside them, we can distinguish different activities like trading, tourism, investment or productivity growth, essential for any region's development.

A lot of things can be done to improve the safety levels of an aircraft or airfield. One of these things is the utilization of radio aids. Radio aids are equipment that operates by transmitting electronic signals received by air vehicles. These facilities supply the pilot with the necessary conditions, enhancing the safety of the flight [9].

By using radio navigation aids, pilots can have a more accurate and safe flight, especially in bad visibility and weather conditions, acting like a valuable backup method for general navigation. Among these equipment's we can find a very important category: the approach systems. The origins of the approach systems existent nowadays go back to 1945 (end of World War II) when commercial aviation was experiencing an unprecedented rate of expansion. For operations to be done in all kinds of atmospheric conditions, new systems were needed and therefore more importance and research was put in this specific field of navigation systems [10].

The approaching phase of a flight occurs when the pilot induces changes on the aircraft's configuration preparing for landing. It usually finishes when the aircraft is ready for landing on a given airfield or even with the beginning of an initial climb or go-around phase. For being very complex flight phases, they often impose significant demands on the pilot [1]. These approach procedures can be traditionally separated into two different types, based on the data they provide: Precision and non-precision.

- Precision approach systems give us both lateral and vertical guidance with some minimum criteria based on the category of operation. Inside these types of systems, we can most commonly find the ILS [11];
- Non-precision approach systems provide us lateral guidance, however not vertical, with VOR being the most common one [12].

While precision approach systems would be the ideal choice for any airfield, from a safety perspective, they can't be installed in every existent one, and the necessary budget regarding its implementation and regular maintenance is a lot of times very expensive and easily discarded as an option, especially if the airfield's overall traffic is low or even if the meteorological context where it is inserted doesn't justify it at all.

To measure these factors among many others, feasibility studies are very important, because they allow an analysis of the pros and cons of starting a project, before investing any considerable amount of time and money into it. Inside those, we can find the technical and economic feasibility studies. The first one concerning the technology and equipment existent or needed for a project to be successful and the second one to evaluate the individual and total costs regarding a possible and logical implementation of the system in question.

2.2. Regional airfields

2.2.1. Definition/Characterization

A regional airfield can be defined as an infrastructure that is primarily serving a given region and its population, operating flights mainly within a country rather than international flights. They are usually located in an area outside a capital city and are a vital point of access to remote locations, helping to feed the bigger airports, by working as intermediates in the whole traveling process, making it smoother. Besides all of this, they also play an important role as congestion relievers to some proximity airports with heavy traffic [5].

These airfields are very important in the aviation scene. Not only they're providing an accessible way of air transport to the population dispersed for the whole country by connecting them, their regions and products, but they are also helping to improve the respective local economy, having a major impact on its regional development.

2.2.2. Catchment area

The catchment area of an airport/airfield can be defined as the area neighbouring the airport, where passengers are still enticed to use its services on behalf of other ones [13]. This area usually incorporates places with a maximum allowable access time between one and two hours or no more than 100km to 200km from the airport itself [7]. Obviously, this simplistic assumption can vary according to numerous factors related to the airport itself and even its location. These areas can be found with different methods, one of them is by drawing concentric circles around airports. While it isn't a rigorous way of determining the real catchment area of an airport, it's a simple approach to analyse where a given airport is drawing passengers and freight from. In figure 2.2, we have an example of different airport's catchment areas, in Poland, determined with the method of drawing concentric circles of travel distance around the airports.

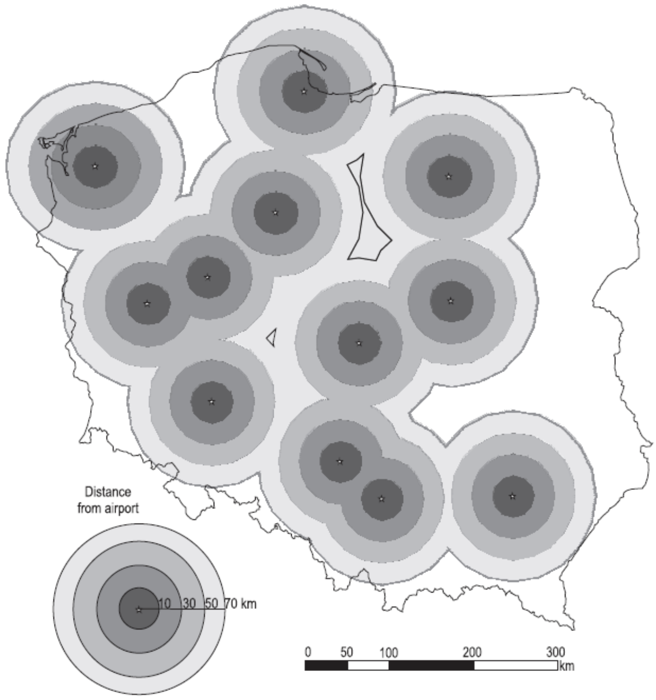


Figure 2.2. Catchment area of different polish airports [14]

Notice that, given the number of airports existing in the country, most passengers should travel no more than around 100km to access the closest airport, making the catchment area of each airport a bit smaller, given its competitor's proximity.

Although this approach is relatively simple to apply, it has some flaws [14]:

- Results in a static image of an airport catchment area;
- Unclear market shares in the catchment area;
- Presents the same catchment area for every destination.

Other methods to estimate the size of an airport's catchment area can be performed and despite being more complex, they are based in models that take into consideration different factors such as the access time, airfares and frequency level. The priority given to these parameters can vary according to the traveller's intents and which aspects they value the most, either it is time or comfort, for example [7]. The size of an airport's catchment area is influenced by the choices that passengers make and their reasons to choose a specific airport instead of others. Most studies show that the most important factors behind airport choice are its access time, flight frequency and/or airfares [7].

Catchment area analysis isn't so simple and straightforward, and this is mostly related to the lack of useful data on this topic since empirical evidence on this matter can only be obtained by passenger inquiries, which can explain the dynamic aspect of this area that is continuously changing.

2.2.3. Economic impact

As most infrastructures, an operating airfield can have a major impact on its region's development and growth. These strategic infrastructures are becoming even more relevant due to the growing importance of air transport in connecting regions in an increasingly modernized society [8]. In the last two decades, air traffic has experienced rapid growth, which is expected to continue in the near future. This increase in traffic leads to some cases of air congestion, pressuring airports to expand themselves [15], and causing different types of impacts, especially on an economic level.

As it has been stated before, we can find four different types of impacts associated with regional airports - direct impacts, indirect impacts, induced impacts, and catalytic impacts [16]:

- Direct economic impacts – The employment, income, and GDP relative to the management and operations of activities at the airport including its firms and surrounding businesses (airlines, airport operators, and other activities);
- Indirect Economic impacts – Employment, income, and GDP relative to the industries and firms that are supporting the activities at the airport by supplying necessary materials and services;
- Induced economic impacts – The employees of firms associated with the airport spend their earnings in the national economy (restaurants, health care, etc.);
- Catalytic economic impacts – Concerns the importance of an airport at smoothing and facilitating the business of different areas in the economy.

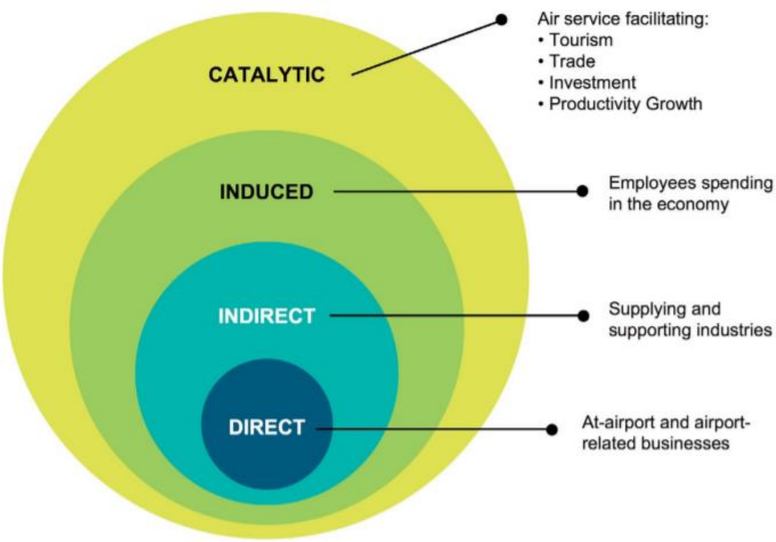


Figure 2.3. Different types of economic impacts generated by European airports [16]

The catalytic economic impacts, as we can observe in figure 2.3, represent a huge portion of all economic impacts airports can bring. The importance of air transportation in simplifying employment and economic development in the national economy cannot be despised and works according to different yet important mechanisms such as [16]:

- Trading - By providing connections between different markets exchanging valuables and services;
- Investment – By deciding the best options to take such as the best location for businesses posts near airports;
- Tourism – By simplifying the arrival of tourists to different regions, as well as their spending in the various sectors of tourism businesses;
- Productivity – By offering access to new opportunities and markets, helping some businesses to pop off besides also attracting and maintaining good employees.

As we can see, economic impacts can be divided into different categories, however in regard to economic development it isn't so easy, and measurement is hard and not consensual, often achieved by surveys, multipliers or even econometric techniques [17].

Multipliers are the most common approach used to quantify the regional economic implications of an airport. They essentially work by identifying immediate jobs associated with the airport and then tracing out the different effects of the incomes spent from these jobs. Despite being a simple approach to apply, the coefficients of the multiplier are not stable and can vary according to different factors related to the economy and to the airport itself [17], making it a relatively weak alternative and opening doors to other ones.

2.3. Radio aids

2.3.1. Introduction

Radio aids represent a crucial part of the whole aviation industry. They provide pilots unmatched safety levels during all phases of flight, from departure to landing, being requisite in modern aviation. Those types of equipment are implemented both in the airfield and in the aircraft and can be either more expensive or cheaper, mainly regarding its installation and maintenance costs, depending on the effectiveness and safety they offer. Inside this branch, we can find the approach systems: a very important category that operates in the approaching and landing phases of flight. This category can be distinguished into two types, based on the information provided: Precision and non-precision.

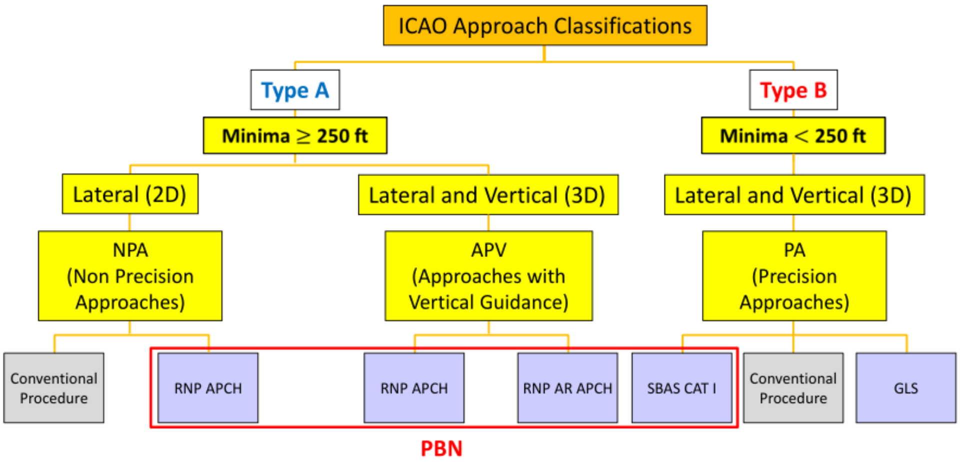


Figure 2.4. ICAO approach classifications [18]

ICAO's classifications models have been changing throughout the years. As seen in figure 2.4 and from 2017 on, they are distinguished in two types, considering the minimum descendent height. PBN is a newly advanced, satellite-enabled form of navigation that creates precise 3-D flight paths, where RNP, RNP AR and SBAS CAT I approaches are included.

While precision approach systems are more efficient, by providing lateral and vertical guidance, they're obviously more expensive than non-precision systems that only provide lateral guidance. The choice between these two kinds of equipment is usually made based on the airfield's perspective, considering its capital, traffic, and evolution throughout the years. In order to select which approach system would most fit this case study, a brief description of the most utilised ones on a global level (mostly conventional procedures) is presented in the next sections.

2.3.2. Approach systems

2.3.2.1. Non-precision

Although precision approach systems seem to be the best choice for any airfield, by looking at the safety and accessibility provided, they can't be installed in every single airfield, with one of the main reasons being the high costs that normally come up with it. That's why sometimes the best option is to embrace a non-precision approach, relatively cheaper and simpler to execute.

Non-precision approach systems only provide lateral guidance, but not vertical. Despite still being very useful, they are less accurate than the other type, especially when operating at very bad visibility and weather conditions. Inside this tier, we can highlight different types such as VOR, GPS, and NDB.

2.3.2.1.1. VOR

A short-range navigation aid that provides azimuth assistance by visual means of cockpit instruments, and is normally used for landing, terminal and in route guidance procedures. The information provided by this system is relative to the VOR station and magnetic north, so aircraft who are properly equipped are able to receive them [19]. This system operates in the VHF band (108MHz-118MHz), by transmitting two signals simultaneously. While one of them is constant in every direction, the other one is rotating around the station. The airborne equipment (VOR antenna, VOR frequency selector and a cockpit instrument) receives both signals and measures the difference between those. This difference is named the radial [20]. The VOR usually coexists with a DME system or even a TACAN system [19], [20], giving pilots a precise indication of the distance between the aircraft and the VOR station.

An example of a VOR/DME approach is shown in figure 2.5.

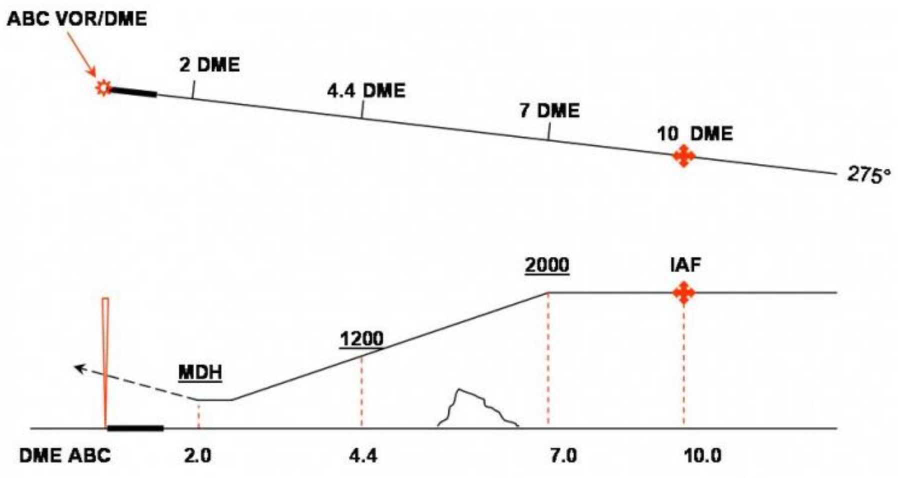


Figure 2.5. A VOR/DME approach [12]

This procedure starts at IAF (10 DME on the ABC 095 radial). The aircraft may not descent below 2000ft until passing 7 DME, after which it descends on the 095 radial. Due to high terrain, the aircraft may not descent below 1200 ft. until it passes 4.4 DME when it continues the descent to the MDH. If the required visual references have not been established before 2 DME, the aircraft must initiate a missed approach [12].

2.3.2.1.2. GPS

This famous American system is one of the four implementations of the GNSS that are currently in existence or under development [21]. It is a satellite-based system (composed of twenty-one satellites, plus three operational spares, in six orbital planes [22]). It provides positioning, velocity, timing, and many other services all around the world, both for civil and military uses by utilizing precise satellite position and onboard atomic clocks, so navigation messages are continuously generated and broadcasted from each satellite to users that wish to process them, determining position and time in a very accurate way (few meters and few nanoseconds, respectively) [23]. This system operates based on triangle principles and is one of the most known positioning systems worldwide, having countless applications in various fields, with aviation being a major one of them [24]. Despite very useful, its vertical accuracy is not enough to be included in the precision approaches category.

2.3.2.1.3. NDB

This is a radio beacon widely used to support in-route navigation and airport approach procedures that operates in the MF or LF bandwidths [25]. This type of approach consists in the transmission of a signal in every direction with equal strength, which contains a coded element necessary for the station identification [26]. The MF transmitter radiates an uninterrupted carrier, which is amplitude modulated to key a two or three letter Morse identifier. The ident is transmitted and after tuning to a particular NDB, the pilot uses the audible ident as a confirmation that the correct beacon has been selected [25]. An NDB antenna can be seen in figure 2.6.

Figure 2.6. NDB radio antenna [27]

2.3.2.2. Precision

Precision approach systems utilise lateral and vertical guidance. They basically give information if you're deviating to the left or right and/or if you're too high or too low, before making any visual contact with the runway and therefore providing higher levels of safety when it comes to this phase of flight. Precision landing systems can be separated into three categories of operations based on ceiling and visibility. With each category, there is associated a decision height: the height above the runway below which a pilot must not descend unless proper visual references have been obtained [28]. For the CAT II and CAT III categories, instrument approach and landing are only permitted if RVR information is provided [11]. They are very useful especially in bad visibility and weather conditions, allowing pilots to have increased safety in these circumstances.

Inside the precision landing systems, we can find a lot of different types of approaches. The most important and frequent ones being ILS, MLS, TLS, PAR, and GNSS Augmentation Systems.

2.3.2.2.1. ILS

The ILS has been the mainstay of landing navigation aids for well over 50 years. This system is composed of two radio beams, which work together to provide lateral and vertical guidance to the pilot during the approach and landing phases. The lateral guidance is provided by the localizer (which aerials are located at the end of the runway) and the vertical guidance is provided by the glide slope (which aerials are usually located on the aerodrome) [29]. In figure 2.7 we can observe a diagram regarding this type of approach and how it is performed.

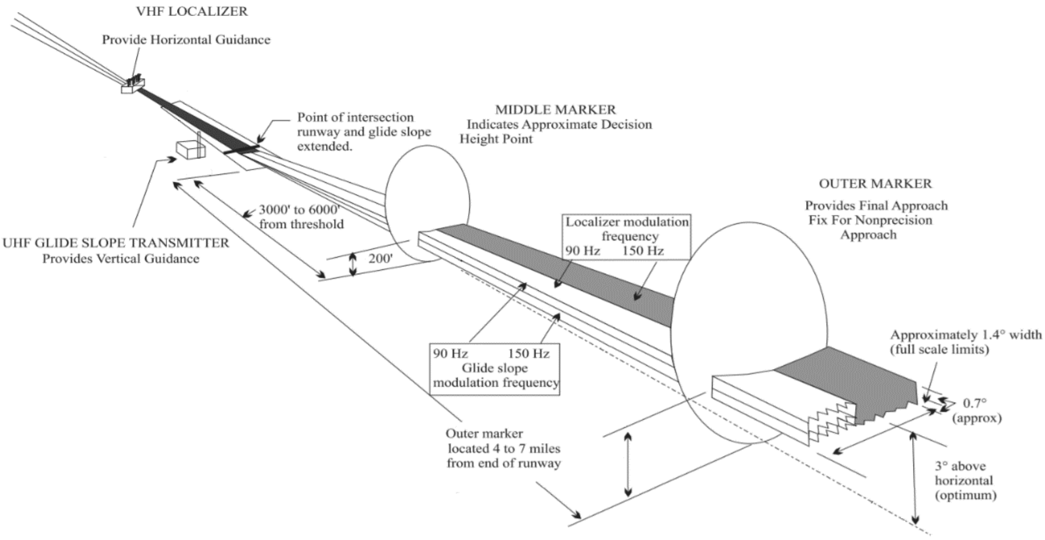


Figure 2.7. An ILS CAT I diagram [30]

In figure 2.7, we can observe the localizer, the glideslope as well as the outer and middle marker, which give information about the aircraft's position relative to the runway. The inner marker, located at the threshold of the runway, is usually utilised in category II and III approaches.

This system is one of the most common precision systems and just like the other precision approach systems, it can be divided into three different classes based on different parameters, exhibited in table 2.1.

Table 2.1. Different ILS categories [31]

ILS	Decision Height [ft]	RVR [m]
CAT I	200	>550
CAT II	100-200	>300
CAT III A	0-100	>175
CAT III B	0-50	50-175
CAT III C	0	0

After reaching the DH, the pilot can only continue the approach to land if the required visual references have been established. If not, the pilot must begin a missed approach procedure [11]. As shown in table 2.1, CAT III C takes place in no DH and RVR conditions, meaning that the aircraft can approach and land under non-visual conditions. This reason, along with the difficulty of ground manoeuvring after landing, makes this category not operational and rarely used on most airports [29], [31].

2.3.2.2.2. MLS

This system was designed to solve the total landing-guidance problem, meeting a wide variety of diverse performance, economic and safety requirements with a common signal format. The wide proportional coverage of the system provides for flexible approach paths and precision self-navigation in the terminal area, supporting a 200-channel frequency plan that permits the operation of some present and future needs that ILS struggles with [28].

It operates on two different channels, where the protractor part of the MLS is continually providing information about an aircraft's position (in the vertical and horizontal plane) relative to the runway. The rangefinder part measures the distance between the aircraft and the reference points in the procedure. The angular information for the approach course is determined by measuring the interval between the two passages of an oscillating plane lobe through an onboard MLS antenna [28], as shown in figure 2.8.

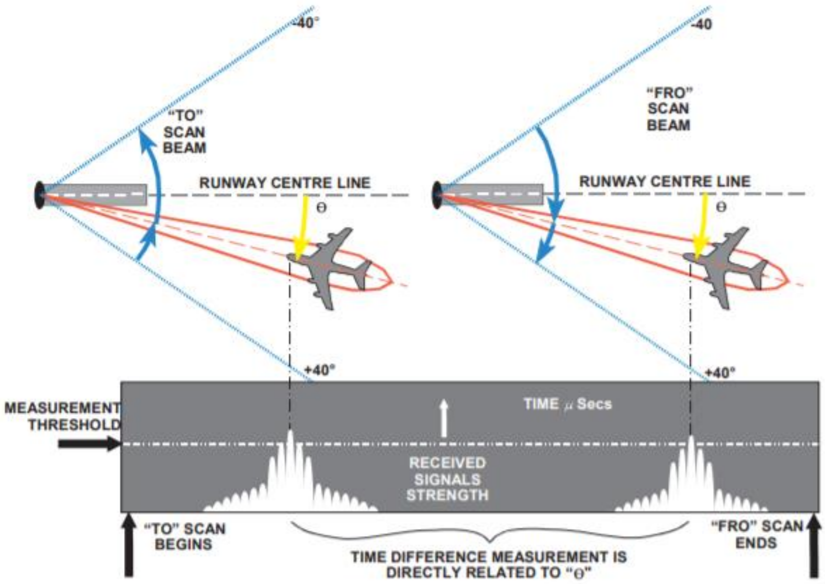


Figure 2.8. An MLS approach [32]

By providing azimuth, elevation, and distance, this system ends up operating on top levels of precision, allowing the aircraft to have an exact alignment and descent towards the runway. It works as an alternative to the ILS system, having significant advantages such as allowing a greater number of possible executed approaches, more solid infrastructures and even the possibility to perform more complex trajectories.

2.3.2.2.3. TLS

This precision approach system is designed for airports where rough terrain or other constraints make ILS installation not viable. All IFR-equipped aircraft capable of flying an ILS is also able to fly the TLS without the need for new avionics. From a pilot's perspective, this kind of approach is similar to an ILS approach [33].

This system determines the aircraft's position from signals emitted by the aircraft's transponder by measuring the time and angle at ground-based sensors. The corrections from the localizer and glideslope are computed and the aircraft is guided to the desired course. The ground-based TLS determines the position of the aircraft by interrogating the aircraft transponder and then measuring its time of arrival, the azimuth angle and the elevation angle. After identifying the location of the aircraft, the correction needed for the localizer or glide slope is determined to guide the aircraft to the desired course [33]. In figure 2.9, the TLS electronics - shelter, the uplink antenna, and the elevation sensor - are visible.

Figure 2.9. TLS facility in Antarctica [34]

2.3.2.2.4. PAR

This tracking system provides the Air Traffic Controller (ATC) the display of an aircraft's precise position relative with respect to the runway final-approach course. The information regarding the position of the aircraft is precisely displayed to ensure absolute safety. The display provides the controller information for heading and rate of descent controlling by showing the aircraft position in relation to range, azimuth, and elevation. This information allows an air-traffic controller to direct a pilot down along a runway approach course to a precision landing [35].

These kinds of approaches are very common in military operations and are very effective in most weather conditions, not requiring any onboard equipment, such as an ILS [35]. An example of the radar is presented in figure 2.10.

Figure 2.10. PAR 2090-US [36]

2.3.2.2.5. GNSS Augmentation Systems

GNSS augmentation systems were developed with the purpose of continuously providing robust and safe navigation especially when high precision or enhanced coverage or availability is required. These systems attempt to correct many of the error sources existing in GNSS. It is basically accomplished by placing a reference station at a precise location where high-accuracy navigation is required [37]. Inside these systems, we can find 3 different types: ABAS, GBAS, SBAS.

2.3.2.2.5.1. ABAS

This system basically augments and/or integrates the information obtained from the other GNSS elements with available information in the aircraft. It can be implemented by the following techniques [38]:

- RAIM – Uses redundant GNSS information to provide GPS data integrity. Nowadays, around 70% of European flights are made by aircraft equipped with GPS and RAIM [39];
- AAIM – Uses information from additional on-board sensors to provide GPS data integrity;
- Integration of GNSS with other sensors to provide improved aircraft navigation system performance.

2.3.2.2.5.2. GBAS

This system uses input data of three or four GNSS satellite signals received at three or four antennae, broadcasting the differential correction message computed from this data by a ground transmitter operating in VHF [40]. This approach yields extremely high accuracy, availability, and integrity necessary for CAT I, and eventually CAT II and CAT III approaches [41]. Figure 2.11 represents a simple scheme of how this approach system operates.

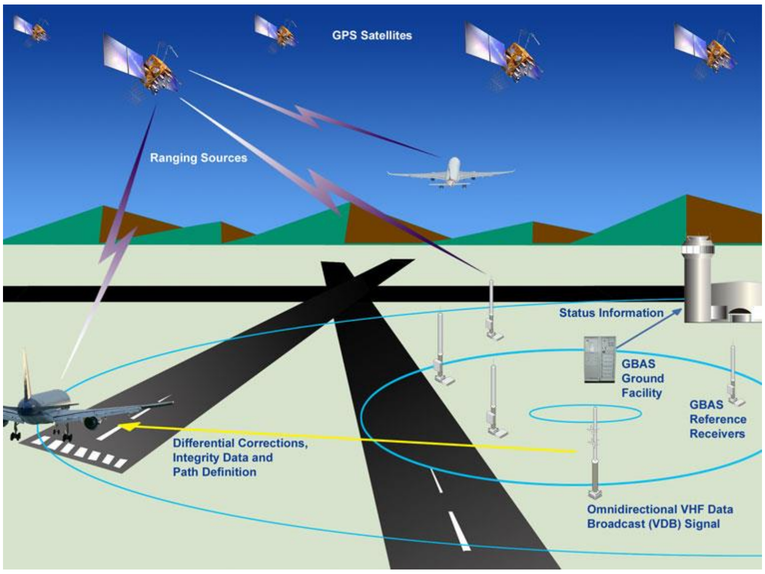


Figure 2.11. GBAS architecture [41]

As we can observe, GBAS is primarily used to facilitate GNSS-based precision approaches that are more flexible in design than the ILS. This system provides signal integrity, whilst increasing its accuracy, with position errors inferior to one meter in both the horizontal and vertical plane. Besides this, it permits that one single ground station of GBAS at an airport supports the approach and landing to multiple runways ends for all GBAS-equipped aircraft [40].

2.3.2.2.5.3. SBAS

This system uses GNSS measurements from accurately located reference stations deployed across a continent. The measured GNSS errors are transferred to a central computing centre, where differential corrections and integrity messages are calculated. The calculations obtained are then broadcast over the covered area using geostationary satellites that serve as an augmentation tool to the original GNSS message.

Several countries and continents have implemented their own SBAS, the most popular ones being EGNOS (in Europe) and WAAS (in the USA) [42].

In figure 2.12, we can observe the different flight phases supported by this system and the previous ground-based one.

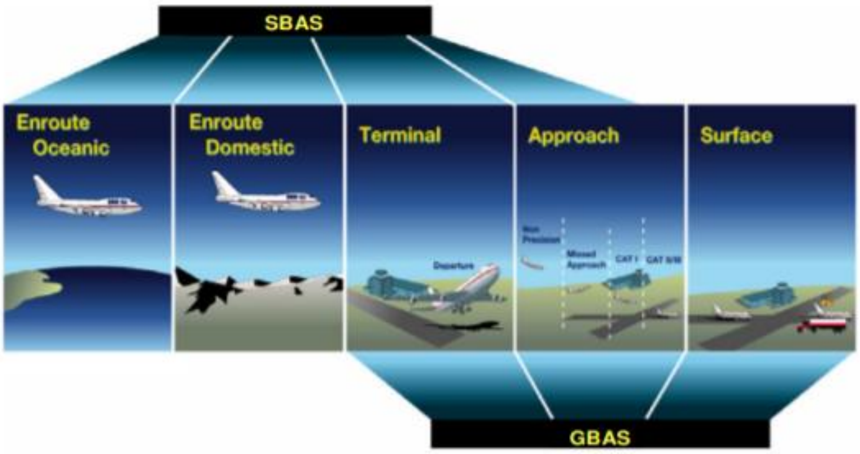


Figure 2.12. SBAS and GBAS supported flight phases [43]

While SBAS can be used in every single phase of the flight except for surface, GBAS is only designed to provide precision information for terminal, approach and surface flight phases. For the approaching phase, GBAS ends up providing more precise information in comparison with SBAS, which works best as an area navigation tool.

2.4. Technical and economic feasibility

Feasibility studies are very important and structured ways to determine how successfully a project can be finished, accounting for different factors that influence it, such as technical or economic ones. These studies are used by various organizations to access development projects or programs, following a specific structure unique to each project [44]. Their main goal is to point out the chances and risks of projects, which are planned or already in the process [45]. We can separate these studies in five different areas according to the acronym TELOS [46]:

- Technical feasibility;
- Economic feasibility;
- Legal feasibility;
- Operational feasibility;
- Scheduling feasibility.

Figure 2.13 explains which questions should be answered for each area, applied in a Health System.

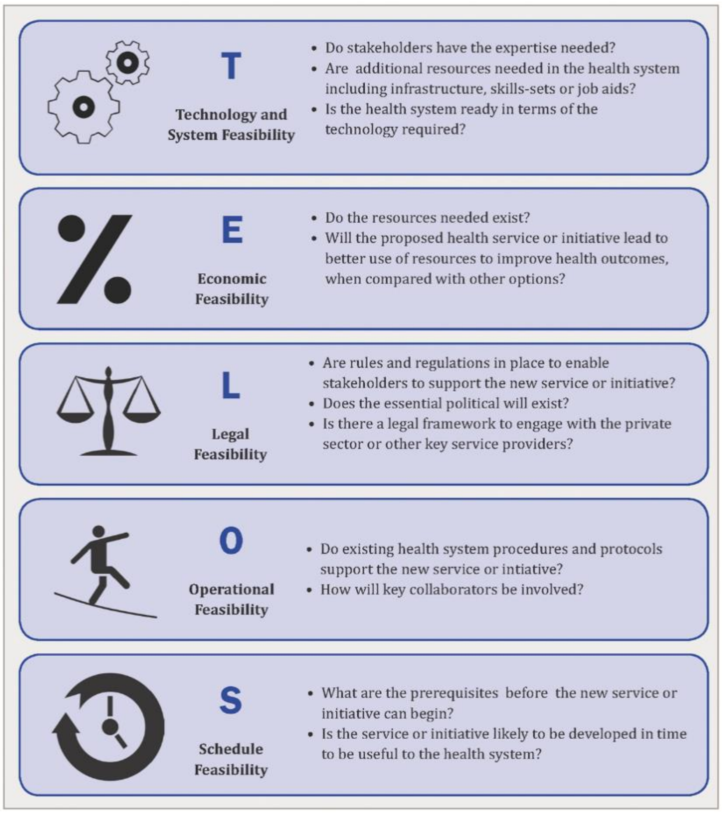


Figure 2.13. Application of a TELOS study in a health system [47]

These studies are done with the purpose of finding out positive and negative aspects that a given project would have, before investing any considerable amount of money and time into it.

In this dissertation, only the first two areas and possibly the most important (technical and economic) will be subject to a deeper analysis, knowing that both complement each other, where the economic study must support the technical one, regarding its information and characteristics.

2.4.1. Technical feasibility

Technical feasibility studies are very useful at pointing out details about how much value could be extracted from a certain good or service, including the technology needed, materials, labour, among many other aspects. They help to identify if the technical resources to form a project or system are available and to which degree, they can support the proposed system, being excellent tools for troubleshooting and long-term planning. These studies concern whether a project can meet its performance objectives with the primary aim to remove uncertainty [48].

In figure 2.14 we can observe how the technical process unwinds, starting in a vision and leading up to economic feasibility.

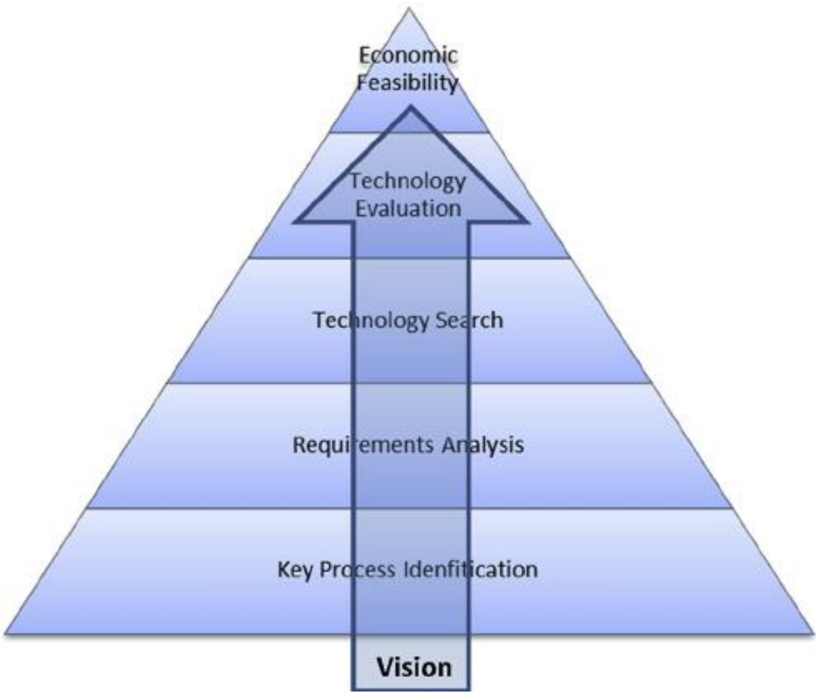


Figure 2.14. A technical feasibility scheme [49]

Once the technological study is established, it is also important to consider the economic factor, because a particular system may be technically possible, but it may require a huge investment that wouldn't justify the benefits that it brings. The present value of a proposed project is directly related to the probability of its success. That's why an economic analysis is important and should be looked to be performed after the completion of the technical studies, to quantify the risk before committing money into it, as shown in the next section [48].

2.4.2. Economic feasibility

Economic feasibility studies should establish the total cost needed for the project, as well as the different points where that capital should be spent. Another aspect to consider is an expectation of the return value that the investment would bring, covering every scenario.

One of the methods to reach a proper and better understanding of a project before initiating it is a cost-benefit analysis (CBA). This systematic approach consists of quantifying the benefits of a project, decision or policy over a certain period, as well as its expenses, analysing also the other alternatives as a form of comparison to obtaining more rigorous and impartial results [50]. Two of the mains purposes in using a CBA are to determine if the project is feasible, by weighing its costs and benefits, and to offer a baseline so different projects can be compared, identifying those whose benefits overcome the costs needed. If an in-depth CBA may be sufficient enough for projects in small-to mid-level capital expenditures with an intermediate time of completion, for long-term projects, this method usually fails to account for meaningful financial concerns such as inflation, varying cash flows, and the current monetary value. Other analysis methods can be more appropriated for these cases.

An example of how a CBA should be performed and which aspects should be considered is illustrated in figure 2.15. By analysing the costs and outcomes, it is possible then to study the outputs, which can be expressed in economic or financial terms.

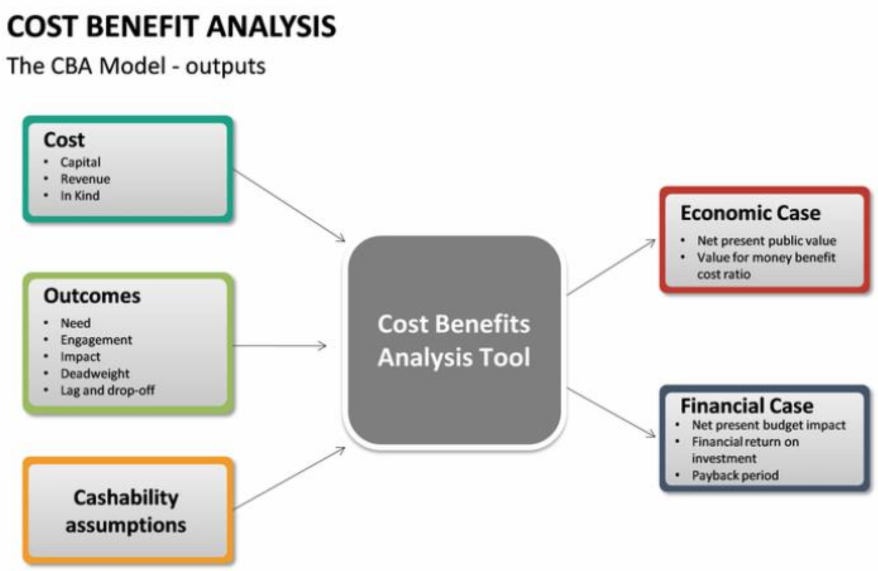


Figure 2.15. A CBA model [51]

The importance of economic feasibility studies is enormous, and they should always be performed, even if the project nature is non-profitable since they will give us valuable information of what we can expect while developing a project in a financial level, as well as the financial resources needed for the completion of the project. If they are profitable, however, the risks that some businesses or other organizations face when making decisions about major investments (products, facilities, technologies) can be analysed with analytical rigor, improving these types of strategic decisions and their success rate, preventing possible big losses of money.

2.5. Conclusion

As we can see, regional airfields represent a very important role in the aviation business. Not only many of them are helping their regions to grow and develop at an accelerated pace but are also providing higher accessibility for the people who search for an air travel alternative outside a big capital city, where most of the big airports exist.

When we talk about airfields, it's mandatory to bring up the safety element. Safety is a key aspect in any field, especially in aviation, where these indices must be at their top. Infrastructures like the airports should seek the best options considering their capability, specifically at an economic level, taking into consideration how valuable and relevant they are in their respective functions. That’s why radio aids are so important in helping to reach the levels these facilities pursue. Among these we can find the approach systems which can be distinguished in precision or non-precision, both being very useful in their own ways, despite their complexity, efficiency and costs differences.

The choice between which proposed system would be the most suitable for each case can be done by performing feasibility studies, which are very helpful analysis tools that take into account different factors and try to measure the ability to complete a project successfully, determining positive and negative outcomes before investing valuable resources into it. The two main categories of these studies are technical and economic. While technical feasibility tries to find out if the current resources and materials are available and can support the proposed project, economic feasibility’s main goal is to weigh the risks and benefits that a project would bring before starting it. The CBA is a great model to perform this economic analysis.

Saying all this, the main objective is about finding out to what extent would it be viable, from a technical and economic view, to implement or improve existing approach systems in airfields that are lacking the safety these systems provide or even if they are looking to enhance it. It is known that those systems can bring many benefits, especially looking at the airfield's evolution, from a traffic perspective, still, these can have a higher or lesser impact, concerning the different constraints present in each case.

Chapter 3 – Case study

3.1. Introduction

The case study used in this dissertation was the case of Viseu airfield. In this chapter, there will be a detailed description of the airfield regarding the importance it has on a national level and the services it offers, as well as its economic impact on the region. To study and analyse the economic factor, as well as the Hinterland of the airfield, inquiries to the most important stakeholders within the Catchment Area were made and the different data was later collected and organised. The two other airports considered were Oporto airport and Lisbon airport. The main objective was to analyse and verify the aerodrome’s strategic positioning to eventually replace the two considered airports (in passenger transportation) for people within the region. This region of Viseu was also an object of study, specifically its evolution throughout the years along with different variables like population and firms. In figure 3.1 the airfield is represented.

Figure 3.1. Viseu airfield [52]

Both precision and non-precision approach systems were also reviewed, along with possible approach charts in order to select the best option that would satisfy this project's needs and expectations with the principal objective of finding the most suitable equipment for this case.

One of the main points also attended was about investigating the period of time needed for the airfield to recover the costs spent on the proposed approach equipment, taking into consideration its longevity and regular maintenance needs. One of the ways to achieve this was by reviewing the total income from the aerodrome’s taxes over the years, forecast its values for the future (with the equipment installed) and find out how long it is needed to retrieve the investment done.

3.2. Viseu airfield

3.2.1. Characterization

As many airfields in Portugal, Viseu airfield also plays a very important role in the development of its region, located in the north-centre side of the country, 6.5km N to the city of Viseu with an elevation of 628m. It used to have an operating VOR-DME system, but now, GPS approaches are being utilised for experimenting and training purposes. It is currently running national flights, being part of a daily (except Sunday) air transportation network that connects Bragança to Portimão performed by SevenAir. Even over, it has just got installed a training centre to produce commercial pilots, as well as cabin assistants and maintenance technicians.

VFR flights at night are also permitted in the airfield if done under certain conditions. Its existing firefighting services and installations, as well as an Aeroclub and skydiving activities, are some of the big assets, not only for the aerodrome but also for the region, to anyone who is searching or requiring them. A full list of characteristics can be found in the VFR manual [53], from NAV. Either it is sought for tourism, leisure or even business purposes, its evolution has been a constant since 2014 (year where the regional air transportation network was also restored), verified by the increasing number of movements of aircraft since that period, making the aerodrome one of the most important and biggest air infrastructures of the centre region in the country at the moment and one of the few with an operating regional air transportation network. The relative proximity to Oporto's metropolitan area or even the tourism growth in the region are two of the major reasons that help the airfield reaching this important status of being a very significant addition to the region it represents, giving people and companies an extra alternative to bigger city airports like Oporto's or even Lisbon's sometimes. In figure 3.2 the airfield's infrastructures can be seen, as well as both runways 18 and 36 and its dimensions.

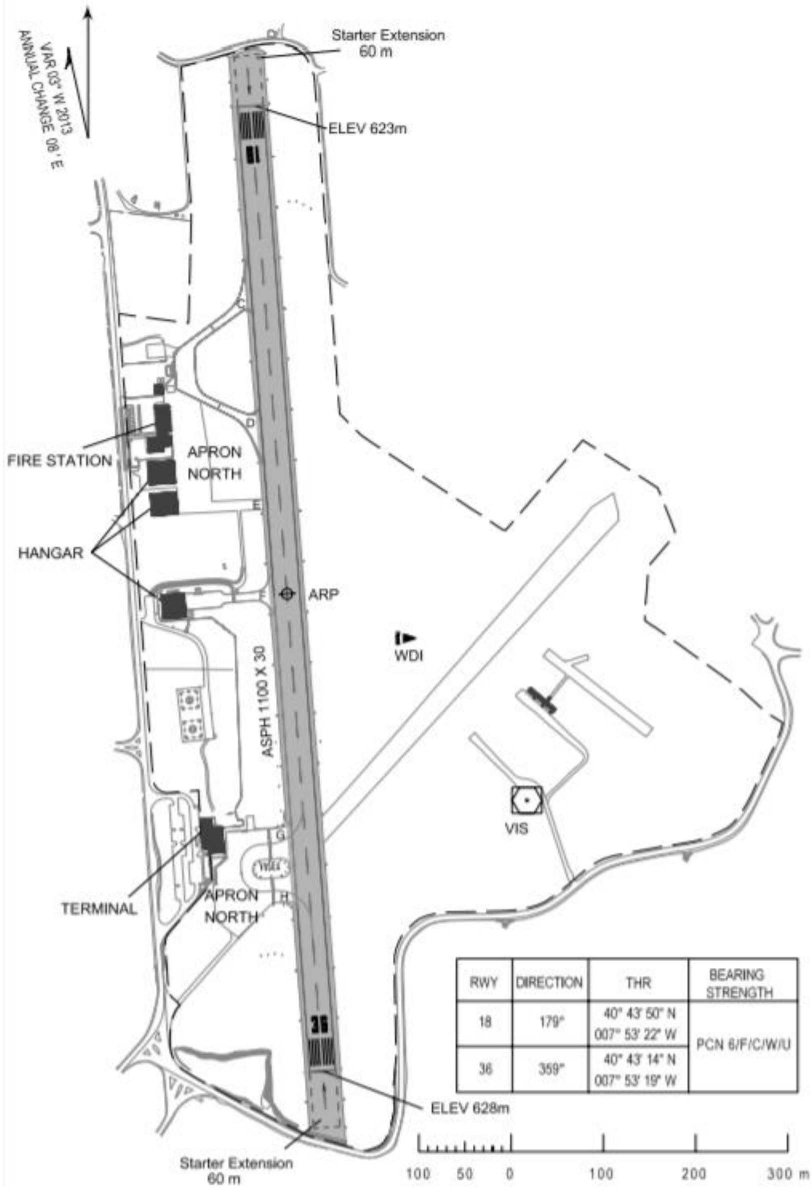


Figure 3.2. Aerodrome chart [53]

One other major aspect to consider in this characterization, and to make sure the implementation of a new system is justified, is to analyse the meteorological context where the airfield is inserted.

If the weather and visibility conditions are usually good during the whole year, an ILS or another type of precision approach system wouldn't bring many advantages to the airfield, since pilots could just perform a simple visual approach to the runway, without the need of instruments, most of the time. However, in Viseu, it isn't the case and in some months, it's very foggy and rainy with high percentages of humidity. These factors make non-precision approaches less optimal for this case and better options had to be considered.

In figures 3.3 and 3.4, we can observe the weather archive from 2009 to 2019, in Lordosa, Viseu, where the airfield is located [54].

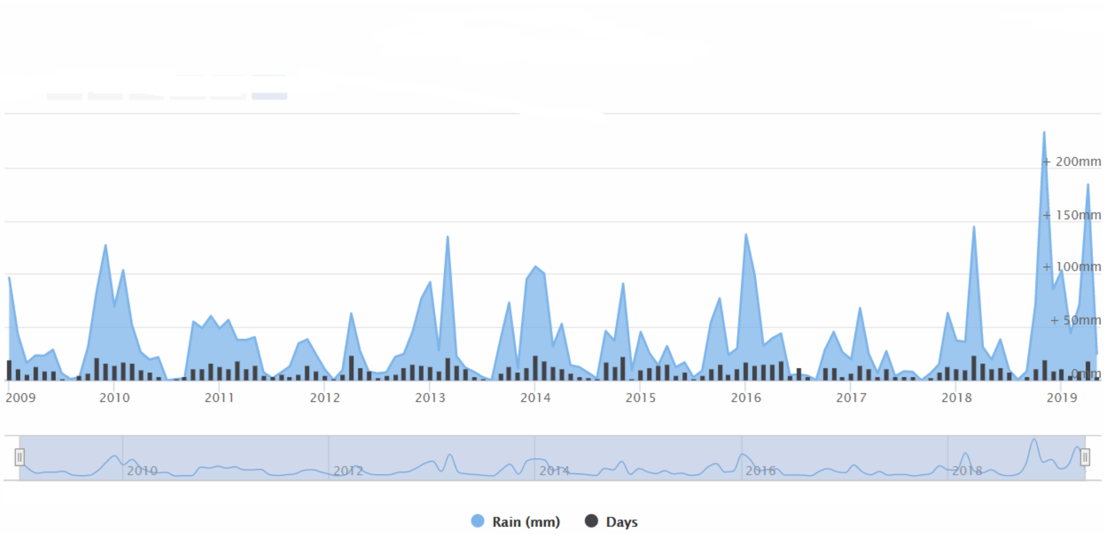


Figure 3.3. Rain (mm) and rainy days in Lordosa, Viseu

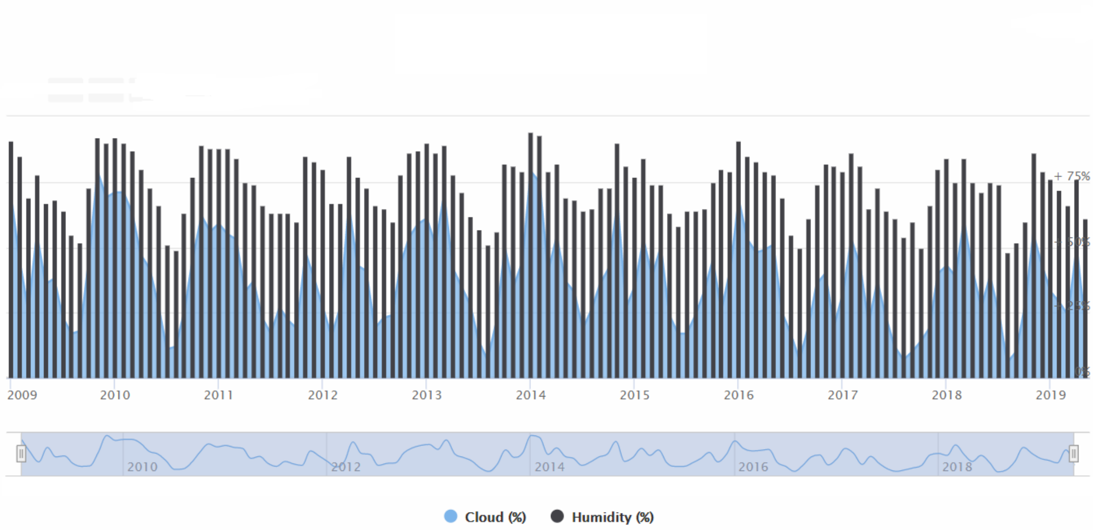


Figure 3.4. Cloud and humidity (%) in Lordosa, Viseu

As can be seen in figure 3.3, in 2019 the rainfall was very intense, reaching peaks superior to 200mm, higher than in most regions of the country. The same happened for the previous years. In figure 3.4, high percentages of cloud and humidity can also be found almost uniformly over the past 10 years.

These bad weather conditions in some months make aircrafts unable to perform a safe landing, causing a lot of inconvenience for the passengers, the companies and for the airfield itself.

Better approach equipment could end up being very useful in some of these cases, allowing aircraft to land in certain conditions where before was very risky or not possible at all.

3.2.2. Catchment area

In the case of Portugal, ANA (responsible for the management of airports in mainland Portugal), defines the Catchment area of the airports by travel time distance. In this work, only Oporto airport and Lisbon airport were considered as the main competitors relative to Viseu airfield.

The travel time designed to determine the Catchment area of each airport, defined by ANA consists of the following [55]:

- Oporto airport: 90 minutes;
- Lisbon airport: 120 minutes.

However, as for Viseu airfield, the catchment area isn't defined. For this reason, the methodology used to define its catchment area was by determining the distance from the aerodrome to the furthest point of Viseu's district (São João da Pesqueira). This distance is 88km, with an estimated travel time of 82 minutes, by a national road (N229). The catchment area of the airfield was defined as a circle with a radius of 88km, centred in the airfield.

The same was done for Oporto and Lisbon airports, but in these cases, as the travel time was already known, regions within 90 and 120 minutes respectively of access time by highways were chosen and the corresponding circles were drawn. In table 3.1, all the different parameters discussed are represented for each one of the 3 airports.

Table 3.1. Viseu, Porto and Lisbon airports catchment areas: travel times and distances

Airport	Furthest point chose	Distance [km]	Travel time [min]	Access road
Viseu	S. J. Pesqueira	88	82	N229
Porto	Mirandela	152	90	A4
Lisbon	Luso	223	120	A1

In figure 3.5, utilizing the data from table 3.1, all the 3 circles with its corresponding radius were represented.

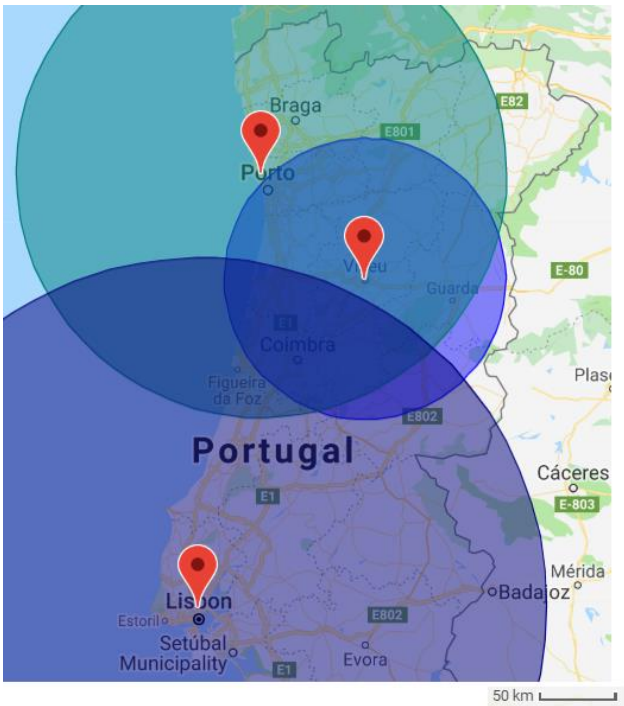


Figure 3.5. Viseu, Oporto and Lisbon airports catchment areas [56]

As we can see, the main competitor regarding Viseu airfield is Oporto Airport, as its catchment area covers almost the whole catchment area of the airfield, unlike Lisbon airport, where its catchment area seems to be covering almost half of the airfield's catchment area.

Despite being a simplistic method of drawing concentric circles to evaluate the Hinterland of the airports, it's still a good comparison tool based on the different access distances and travel times to each case, knowing that most of the business points in the district of Viseu are inside its catchment area and mostly near the principal roads and highways of the region (A25, A24, IP5, IP3 and some national roads like EN229).

3.2.3. Economic impact

The economic impact of Viseu aerodrome is immense. All four types of impacts (direct, indirect, induced and catalytic) can be found by analysing the existing entities and firms.

The principal type studied is related to the economic impact associated with the implementation of a new approach system in the airfield. To evaluate this, the number of existing aircraft movements in the past years was reviewed, analysed and a projection of the movements for the next years was elaborated. The total cost of the system was estimated in addition to the revenue resultant from the aircraft taxes. By doing this, we aim to have an idea of how many years would be needed for the revenue from the aerodrome's taxes, but mostly from some external financial help to neutralize the total cost of the equipment in question. By comparing different equipment costs and performances, it is possible to choose which of them will most fit the project needs, ensuring that the investment doesn't end up being more expensive than it should be for this case.

In order to understand the impact of Viseu airfield, it is also necessary to study the importance of Viseu as a region and its evolution throughout the years. To achieve this, different variables were studied. Two of them were its resident population and firms. After analysing and gathering data on this topic, it was possible to obtain figures 3.6 and 3.7.

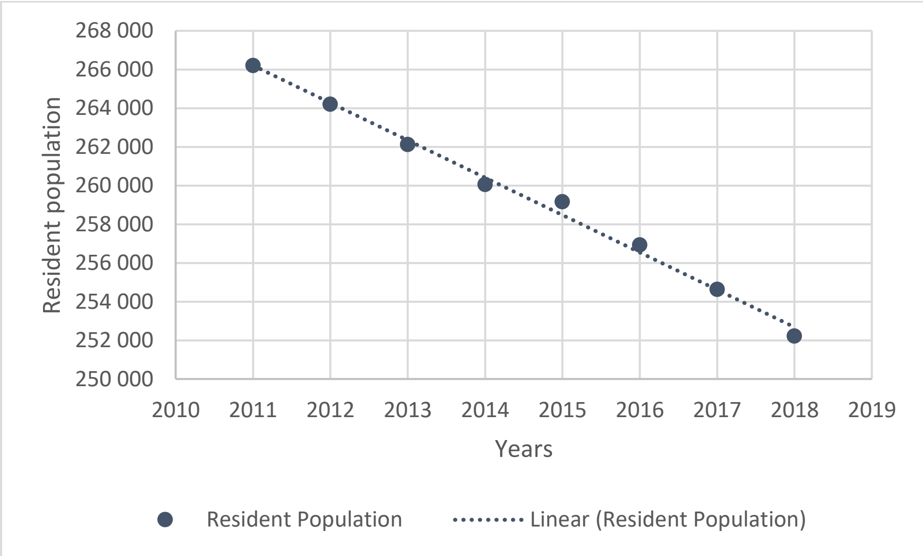


Figure 3 6. Resident population in Viseu (2011-2018)

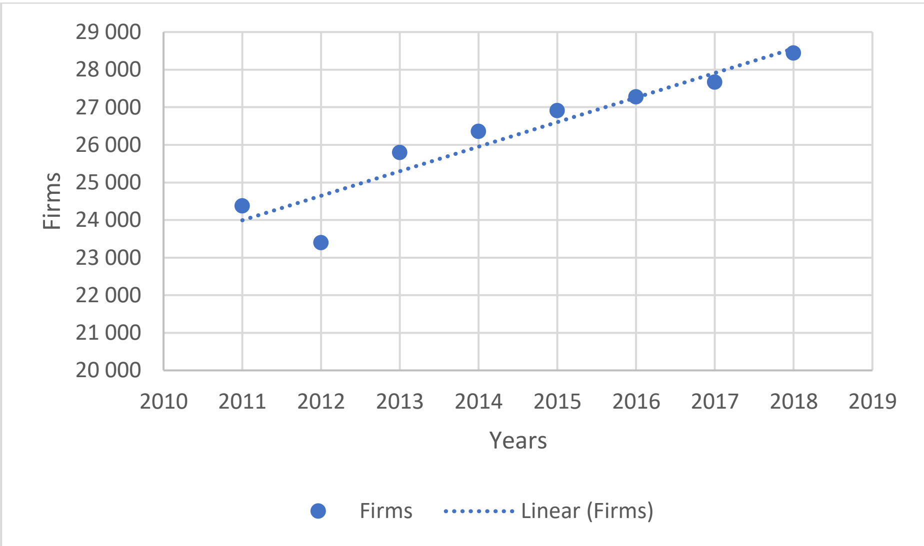


Figure 3.7. Firms in Viseu (2011-2018)

Despite the resident population is decreasing, the number of firms is growing at a very good pace. With this data, found in INE [57], it was possible to elaborate a forecast for the number of movements in the aerodrome for the following years, by relating them with the growth rate of the companies in the district. We utilised this variable, because, in comparison with the other, the model obtained was the one with the most relatable and expected results, considering the variables evolution over time, as seen in table 3.2.

Table 3.2. Firms and movements (2016-2018)

Year	Firms	Movements
2016	27276	9219
2017	27670	10976
2018	28064	9908

Thus, figures 3.8 and 3.9 were obtained. The first one was achieved by forecasting the movements in the function of the number of firms from 2019 to 2029. In the second figure, a variable change occurred from the number of firms to the corresponding year. The R^2 remains the same, but the number of movements can now be calculated by using the respective year, which seems to be more reasonable. For this reason, the graphics in the figures are similar.

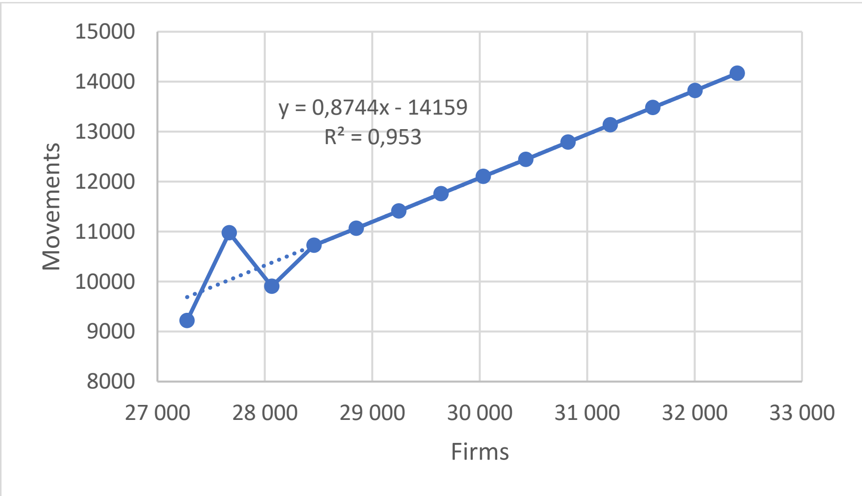


Figure 3.8. Movements forecast (multiple linear regression model – firms)

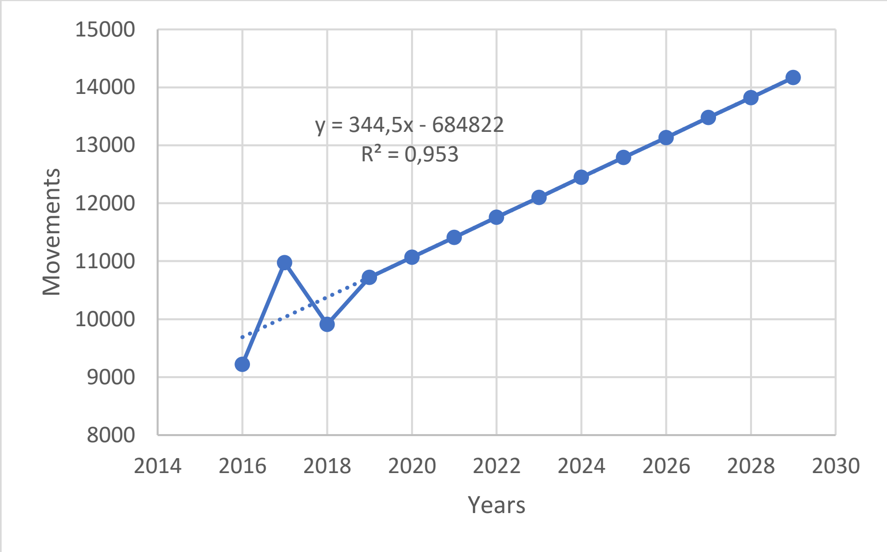


Figure 3.9. Movements forecast (2019-2029)

The tendency lines were obtained by using linear functions. We utilised these functions because, in comparison with the others, they were the ones with a higher value for R^2, ensuring more accurate results. The R^2 (coefficient of determination) can vary from 0 to 1 and is a statistical measure of how close the data are to the fitted regression line. The R^2 obtained of 0,953 means that the model can explain 95,3% of the real outcome.

The only real values considered for the movements in the aerodrome were from the years 2016, 2017 and 2018, given the high discrepancy with the previous 2 years, where the utilization of the airfield was very scarce. The only decrease in movements since 2014 was found in the year 2018, which can be explained by the bad weather conditions verified in the same year. In 2019, the forecasts are for the movements to greatly increase, given the high number of movements in the first 3 trimesters and the newly existent INEM helicopter.

Another study was done for IATA, which has predicted an increase of 3.9% (2014-2024) and 3.4% (2024-2034) in the airfield movements, as shown in figure 3.10.

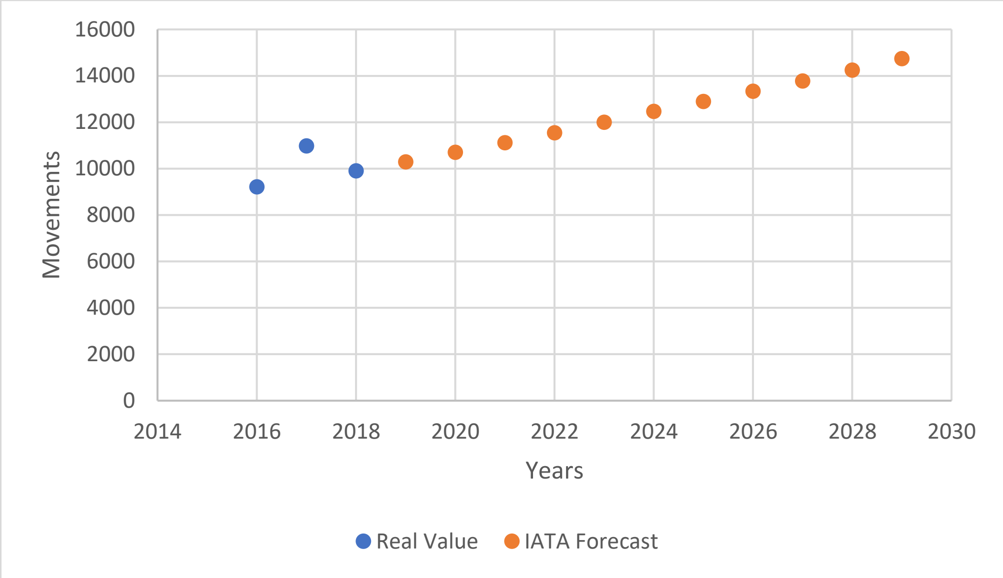


Figure 3.10. Movements forecast – IATA (2019-2029)

As can be observed, the number of movements is expected to increase, following a linear function and keeping up with the previous values registered. It is also of particular interest to note that the first forecast method (firms model) is very close to the actual IATA predictions (with a difference of 19 fewer movements in the year 2024, i.e.). As said before, in 2019 the number of movements is expected to be higher than the value predicted, making these forecasts a little bit conservative, because the actual values are expected to surpass them.

To really understand the economic impact of the implementation of a new approach system and how costly it ends up being in the end, we need to look at the taxes in the airfield. For this case, given the lack of information on this topic, an estimative had to be done, based on the airfield movements, essentially the component from the regional network, performed by SevenAir (which covers up the major part of the income). This network operates daily (except Sunday) and 52 weeks every year, with 4 movements in the summer and 2 in the winter. Obviously, in some days the number of movements decreases, either because of bad weather conditions, making it unable to perform a safe landing, or even if there aren't any passengers to land/board. For this work, those cases weren't studied and the ideal scenario was considered. The results will be shown and analysed in the next chapter.

3.2.4. Inquires to the stakeholders

One of the most important areas of measurement in applied social research is the survey. This method consists in determining any measurement procedures by asking questions to the respondents. The technique utilised for this case was an E-mail based survey, defined as an instrument delivered through electronic mail applications over the internet [58].

To analyse the impact of Viseu airfield as an element of business location and development, surveys were elaborated and delivered to the biggest companies currently in action in the district of Viseu. The main purpose of this survey was to evaluate the Hinterland of the aerodrome, relative to the big national airports of Oporto and Lisbon, as well as the main factors associated with the airfield that lead some companies to choose it over the other alternatives, either it is for passenger transportation or freight, with the main objective of determining the overall impact the aerodrome has in its region. This survey can be accessed at [59] and found in Annexes A (survey) and B (survey results).

3.3. Approaching systems

3.3.1. Non-precision

As it's known, non-precision approach systems don't offer precise vertical guidance, even though some of them end up being very efficient benefit/cost-wise. For this analysis, those systems weren't considered, since the major benefits for the airfield arise from a precision-based system and not this type. At the moment, the airfield is using GPS non-precision signals to guarantee a safe approach and landing phases for the aircraft.

3.3.2. Precision

Now, unlike the previous type, precision-based approach systems offer top levels of exactitude at this phase of flight. For this reason, they are more expensive. After analysing most of these types of systems, the options considered and that would most fit this case study were an ILS and GBAS. This choice was made based on the efficiency that equipment provides, being relatively cheap to install and operate than the other options (showing positive results all over the world). In addition to these reasons, the newly implemented flight school in the airfield will massively benefit from the installation of a precision-based system for training and performing precision-based approaches in instructional flights, very useful for pilots aspiring a career in commercial aviation. In the next chapter, there will be a detailed comparison between the two systems suggested.

3.3.2.1. Approach charts

Approach plates are printed charts of instrument approach procedures used during IFR approaches. They are crucial for aircraft to perform safe landings in bad meteorological conditions, providing important navigation information and allowing aircraft to transition from the in-route segment to a safe approach and landing on the desired runway [60].

At the moment, Viseu airfield utilises GNSS based approach charts, but only for training purposes. These satellite-based charts provide information about the airfield orientation, the obstacles near the runway and the radio frequencies to utilise and contact the ATCs. In the next chapter, examples of approach plates for the new system chosen will be presented.

3.4. Conclusion

This chapter relates to the case study of Viseu aerodrome with the main objective of exposing the importance it has in social and economic terms, especially for the region it represents. This exposure was done by elaborating surveys delivered to the biggest companies acting in the region with the main goal of evaluating the impact the airfield produces, from a business perspective, compared to the big Oporto and Lisbon airports. This importance was verified to be tremendous for most companies. A very simple study of the region's development was executed in the form of its resident population and companies' evolution throughout the years. By using a multiple linear regression model, utilizing the companies as a variable, movements forecasts were performed for the next 10 years. Another movement's forecast method was done for IATA forecasts and the similarity was evident. A simple analysis of the Catchment Area was also performed, and the main competition verified was Oporto's airport, which can be explained not only by its proximity but also because it's one of the big HUB's in the country.

The meteorological archive was briefly analysed, and some bad weather conditions in some months were evident. Existent approach plates on the airfield were examined and two precision approach systems were proposed: ILS and GBAS.

Chapter 4 - Results analysis

4.1. Introduction

In this chapter, the results previously gathered were discussed, analysed and the economic impact of the proposed system on the aerodrome and its region was verified. The technical and economic feasibility studies could finally be performed and based on all the data and results, a solution that would most fit the case study characteristics was found. The results from the surveys were also evaluated and a brief discussion on the answers provided was done.

In the following sections, each of the points cited was separated, studied and conclusions for each one were withdrawn.

4.2. Economic impact

To understand the economic impact of the aerodrome, it is first necessary to study and analyse how the region of Viseu has been developing throughout the years.

As the previous graphics show, the resident population in the region has been decreasing. One of the big reasons for this matter is the existence of an ageing population, one of the highest in the country. Despite this, the number of firms has been growing, and currently almost reaching the number of 30000. Not only this, but tourism has also been expanding, with a verified growth of over 29% in the last 8 years [57].

From this data, we can conclude that the region of Viseu has been progressing at a very good pace, with plenty of new job stations being created every year. The search for this region for tourism and business purposes is evident, two major areas where the airfield contributes the most.

When it comes to the surveys section, after analysing and reviewing its answers, it’s clear that the big majority of the companies surveyed utilise airport services for their business purposes. The results show that every company utilises the airport for passenger transportation and almost half of them also require it for freight. The biggest factor associated with the current or future use of an airport as a strategic partner in its commercial relationships was found to be the airport’s proximity, followed by the available destinations they offer and its accessibility to the road network.

Despite the main airport utilised by the companies being Oporto airport, while Lisbon and Viseu airports having similar usage, most of the companies would prefer to utilise Viseu aerodrome over the other options (if some changes were to be performed), by a large margin. Only 2 companies surveyed chose to utilise Oporto airport, and only 1 chose another airport. The increase in this preference can be justified by various factors, the main ones being the available destinations, the flight's schedules and the existence of parking spots. The ticket price is also a very important reason for this preference, where half of the firms surveyed would require them monthly. The car was found to be the favourite mean of transportation to reach the aerodrome, 75% of the time being a company's car.

In regard to freight transportation, Oporto airport is the main source for these services, even though Viseu airport would be the preferential choice for this case. The main reasons for this preference are its geographical location, a possible increase in its storage capacity, the cost of the services and an expansion of the available destinations.

Overall, the main factors that influenced the current company's location were its accessibility to the road network, followed by the available logistic services and the economic profile of the region. The proximity of the clients, as well as the international accessibility, were also two of the major reasons. A big portion of the companies consider that the location of the airport had some influence in the business's location, however, almost a third of them consider that the airport's location didn't have any importance in their current company's site.

As expected, the utilization of an airport brings out many benefits, the main ones identified by the companies surveyed were an increase of business trips, followed by an increase of the business partners (distributors, providers), and an increase on the companies' turnover.

After reviewing all this data, it is clear and safe to say that Viseu airfield has a lot of future potentials. Acting as the main preference over Oporto and Lisbon airports for local companies, its utilization is expected to be growing in the following years. Although companies mainly use it for passenger's transportation, some improvements especially in its storage capacity, as well as in the available destinations (the existence of short-term international flights) and in the road network to the airfield, would lead the aerodrome to be more and more an option for firms who also require freight transportation. Its location, relatively close to the city and where most firms are established is also a crucial factor for this expected growth and development. It's safe to say that both the airfield and the region would beneficiate from the installation of a better approach system, given the expected increase of movements to be registered.

4.3. Technical feasibility

As said before, technical feasibility concerns whether a project can meet or not its performance objectives. It's about finding out if the equipment and procedures are available and can be utilised when requested. In this case, although it isn't so easy to precisely determine that criterium, there can still be performed a balanced evaluation on this topic by talking to technicians specialized in this area, particularly to people working in this environment and responsible for the airfield. After doing so, it was determined that the aerodrome had the conditions needed, despite the equipment not being currently owned but able to be purchased.

Currently, the approach system utilised is a GNSS/GPS based one, which offers precision information for landing but with possible errors on its accuracy. It's similar to an ILS but without a ground emitter and a lot cheaper, only utilised in the airfield for training purposes.

The first equipment considered was an ILS and the equipment needed would be a localizer (for the lateral guidance) and a glideslope (for the vertical guidance), as well as an ILS receiver in the aircraft. There are two available runways in the aerodrome: 18 and 36. What normally happens in most of the airports/aerodromes in the country is that the approach equipment is installed in the North runways (since the wind usually comes from the south side). However, in this case, it doesn't really matter, because when the weather is bad, it's usually windy, and most of the times aircraft are not able to land in those conditions. Because there isn't any obstacle near runway 36 (South) as opposed to runway 18, it makes this side of the runway the preferable choice to install this kind of equipment (knowing that one ILS installation for each runway end wouldn't be efficient).

The second type of equipment analysed was a GBAS. By utilizing a GLS landing system, the effectiveness of the GNSS can be amplified, and more precise information, crucial on the approach phase can be provided.

The equipment needed for this system consists of 2 to 4 GNSS Reference Receivers and their respective geographically separated antennas, a VHF data broadcast (VDB) transmitter, a monitor system, approach database, and ground processing functions (needed to be acquired for the airfield). For the inboard equipment, the essential elements are an Aircraft GNSS Receiver Function, a VHF Data broadcast receiver function, and an Aircraft navigation processing function.

It should be also noted that the introduction of GNSS-based operations will allow the decommissioning of some traditional navigation aids, as described in figure 4.1. As can be seen, for many years ILS was the preferential choice for most airports. However, in the last years, in the approach, landing and departure phases, its importance has been diminishing, especially for CAT II/III operations, being substituted for satellite-based systems which can also provide in-route information.

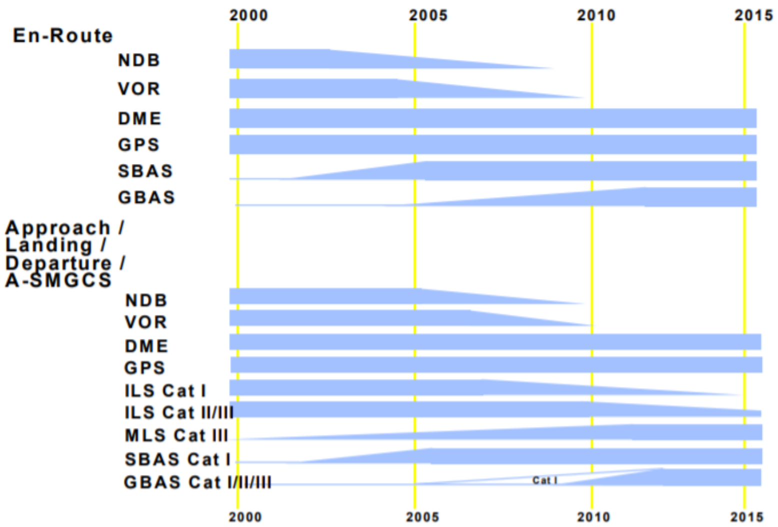


Figure 4.1. ECAC navigation strategy roadmap [43]

From a technical point of view, the go-to system would be the GLS [61]:

- One simple station of this system has enough coverage for all the runways at the installed airport, unlike the ILS where it can only cover one runway end;
- The number of users per approach is unlimited, as opposed to ILS where only one single user is permitted;
- 26 approaches from 1 ground station, as opposed to 1 from ILS;
- More flexible approaches: multiple glide slopes, thresholds, offsets, and no ILS critical area, reducing flying time and fuel consumption.

The main disadvantage associated with this equipment is its full dependence on GPS, where some unwanted interferences in the signal could end up disabling the whole system, and possibly an airport and its runways. It is also important to note that flying a GLS is basically the same as flying an ILS. The procedure, the displays, and the warnings are all the same for an ILS, keeping GLS training to a minimum.

At the moment, Honeywell's SmartPath GBAS is the world's only certified satellite-based navigation and precision landing system. The current SmartPath SLS-4000 GBAS is certified to Category I (CAT I) precision landing. The SLS-4000 CAT I system available today has a defined technical solution that will meet the requirements for CAT II/III GBAS [61]. In figure 4.2 the different components of the landing system and how they interact with each other can be observed.

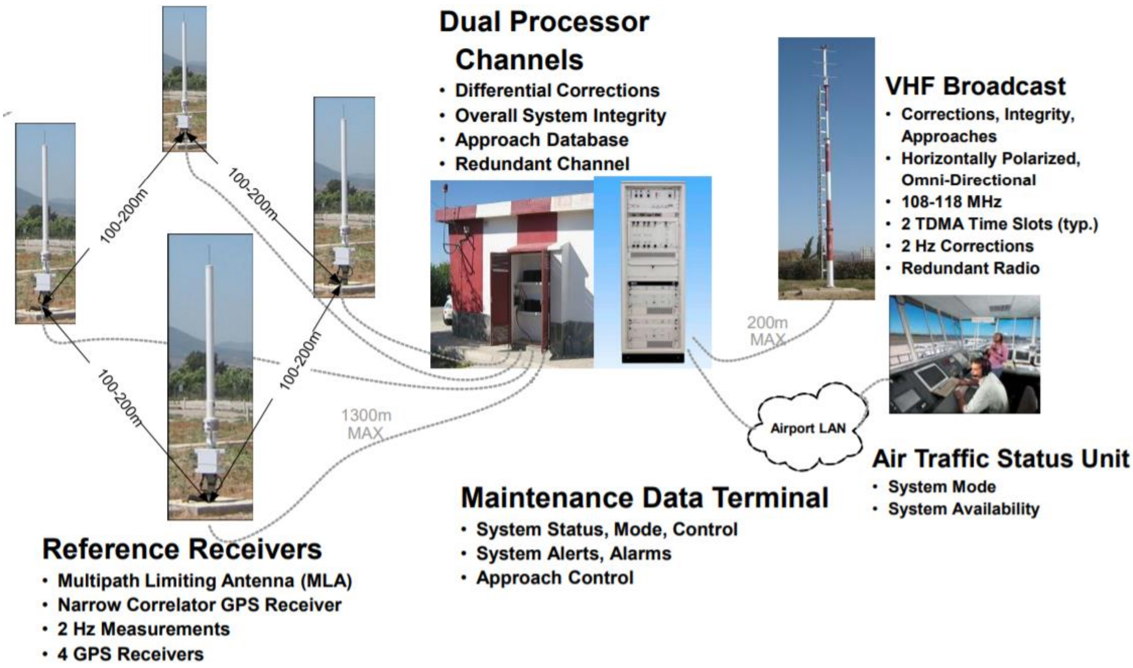


Figure 4.2. Honeywell's smarthpath GBA [62]

4.4 - Economic feasibility

Economic feasibility studies are almost always related to a CBA. In this case, the study was based on analysing the past and the current number of movements in the aerodrome, its correspondent taxes and to estimate, by utilizing forecast methods, the number of movements and the total income from the taxes for the following years. After achieving this, it was possible to obtain an estimative of the necessary time to retrieve the investment done in the equipment, possible increases in traffic and benefits it would bring to the airfield. The value obtained was then compared with the investment needed for each equipment. Despite the necessary income not being primarily related to the airfield taxes, some external and easily acquired financial help would probably make this project feasible. A European investment project can fund about 80% of the total costs of the investment. Before the 15% increase in the airfield taxes, their values are represented in table 4.1.

Table 4.1. Total taxes value (2018-2020)

Year	Movements	Paying Movements 60%	Taxes [€]
2018	9908	5945	47152,80
2019	10294	6177	48980,81
2020	10696	6418	50891,06

In figure 4.3 we can observe the evolution of the taxes predicted for the next ten years, with the equipment installation happening in 2021.

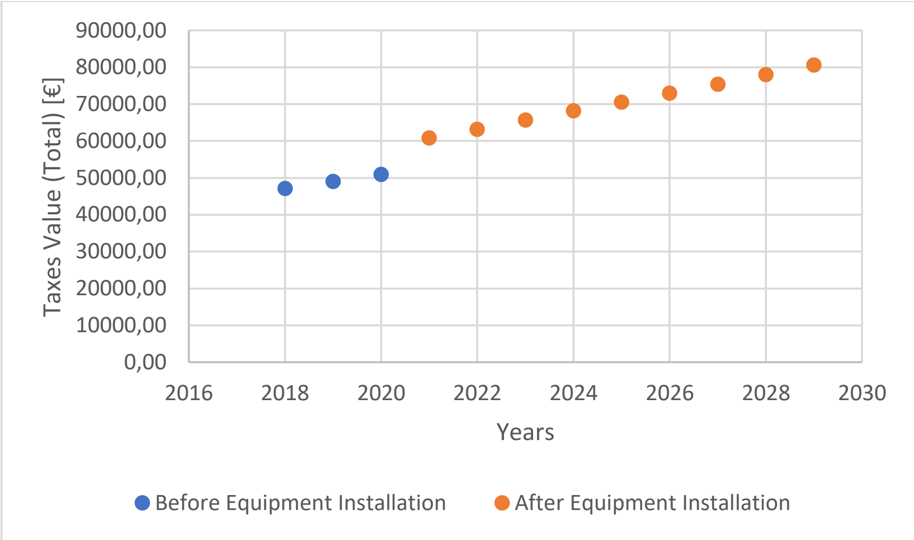


Figure 4.3. Viseu airfield taxes forecast

For this estimation, and because both forecast methods were very similar, the less conservative option was utilised (since the number of movements in 2019 is expected to be higher). So, we considered the IATA movements forecast until 2029, and that 60% of all the movements in the aerodrome were paying the fixed taxes values (mostly SevenAir), presented in table 4.2.

Table 4.2. Airfield taxes (obtained from the airfield owner)

Type	Taxes	
Day/ton	12,38€	
Night/ton	18,46€	
Parking (>2hours)	Inside Platform	Outside Platform
	11,73€	6,52€
For services offered (luggage)	0,87€	

Parking and luggage services taxes weren't considered (given their very low amount). The same happened for night taxes, because of the scarce utilization of the airfield at that period (30 and 18 movements in the years 2017 and 2018, respectively).

After calculating, and estimating that the equipment would be installed in 2021 (a reasonable date), it was determined a total value of 635 246€ (from 2021 to 2029) after the installation, from the taxes only (with a 15% value increase in the taxes from 2021, after the installation), as shown in table 4.3.

Table 4.3. Total taxes value (2021-2029)

Year	Total Movements	Paying Movements (60%)	Taxes [€]	Total (cumulative) [€]
2021	11113	6668	60807,19	60807,19
2022	11546	6928	63178,67	123 985,86
2023	11997	7198	65642,64	189 628,50
2024	12465	7479	68202,70	257 831,2
2025	12888	7733	70521,59	328 352,79
2026	13327	7996	72919,32	401 272,11
2027	13780	8268	75398,58	476 670,69
2028	14248	8549	77962,13	554 632,82
2029	14733	8840	80612,85	635 245,67

The next step was to analyse the differences in the equipment's price: installation and others. The first equipment considered was an ILS, and the estimated costs are represented in table 4.4.

Table 4.4. ILS CAT I associated costs (adapted from [63], [64] and [65])

<table>
<tr><th>ILS CAT I installation costs</th><th>Price [€]</th></tr>
<tr><td>DME and ILS CAT I infrastructure</td><td rowspan="2">1 500 000</td></tr>
<tr><td>Installation and commissioning</td></tr>
<tr><td>Civil works</td><td>195 000</td></tr>
<tr><td>Calibration</td><td>30000</td></tr>
<tr><td>CAT I operation costs (per year)</td><td>79000</td></tr>
</table>

This gives us a total cost of 1 804 000€ in the first year of operation plus the direct costs to some airlines in obtaining the necessary onboard equipment (an ILS receiver). In a 10 years period time, the costs would be 2 515 000€. This value is very high and superior to the total value obtained from the taxes, making it a lot expensive for this case. The second equipment considered was a GBAS, with its costs represented in table 4.5.

Table 4.5. GBAS CAT I associated costs (adapted from [43])

GBAS Cat I Installation costs	Price [€]
Infrastructure	500 000
Civil works	44000
Installation and commissioning	120 000
Initial flight certification	30000
Operating cost (per year)	43000

The infrastructure costs are obtained from the ground station, the VDB transmitter and GNSS receivers. Civil works are needed in the execution of platforms for the station and antennae. Installation and commissioning costs include the initial study, site survey, installation of new equipment and commissioning. As opposed to ILS, the flight calibration is basically a flight certification, since there are no parameters to be adjusted in the GBAS system. The operating cost includes all the spare parts and consumables needed to assure the equipment maintenance, staff expenses and flight certification [43].

It can be observed that the main part of the investment comes from the infrastructure and its installation. Operating costs (maintenance) are also very significant, summing up to 430 000€ over 10 years.

The direct costs to the airlines for a GBAS capability are the purchase, installation, integration, certification, and maintenance of the GNSS airborne equipment, training related to its use and the potentially significant cost of taking the aircraft out of operation for the installation [43]. After summing up the values, we get a total cost of 737 000€ for the first year of operation. For the following years, and over a period of 10 years, the total operating costs were calculated to be 387 000€. This gives us a total cost of around 1 124 000€ over 10 years.

By comparing both values, it is easily noticed that a GLS implementation would save up to 1 067 000€ compared to an ILS system in the first year of operation, and even more in the years to come (1 391 000€ over a 10-year time). GBAS also requires less frequent flight inspections compared to those required of ILS systems. This reason, together with very cheaper and fewer maintenance needs are what make this kind of system a lot better, in economic terms.

Since a European investment project could fund around 80% of the total investment, it was also determined how many years the airfield would need to retrieve only 20% of the equipment, as shown in table 4.6.

Table 4.6. Breakeven point (with 80% fund)

GBAS CAT I	2021	2022	2023	2024	2025	2026
Equipment cost [€]	694 000	-	-	-	-	-
Equipment cost with 80% fund [€]	138 800	-	-	-	-	-
Operation costs [€]	43000	43000	43000	43000	43000	43000
Revenue [€]	60807,19	63178,67	65642,64	68202,70	70521,59	72919,32
Balance [€]	-120 992,81	-100 814,10	-78171,51	-52968,81	-25447,218	+4472,11

The revenue is directly related to the total capital obtained from the charged fees, every year. As can be observed, with 80% funding on the equipment, and taking into consideration the annual operation costs (maintenance), only by the end of 2026 the GBAS CAT I installation would start to be profitable for the airfield. An ILS installation would be much more expensive, since just the annual operational costs by itself are already higher than the revenue, and only by 2029 these costs would start to be refunded. For this reason, the same table for ILS equipment wasn't designed.

4.5. Approach charts

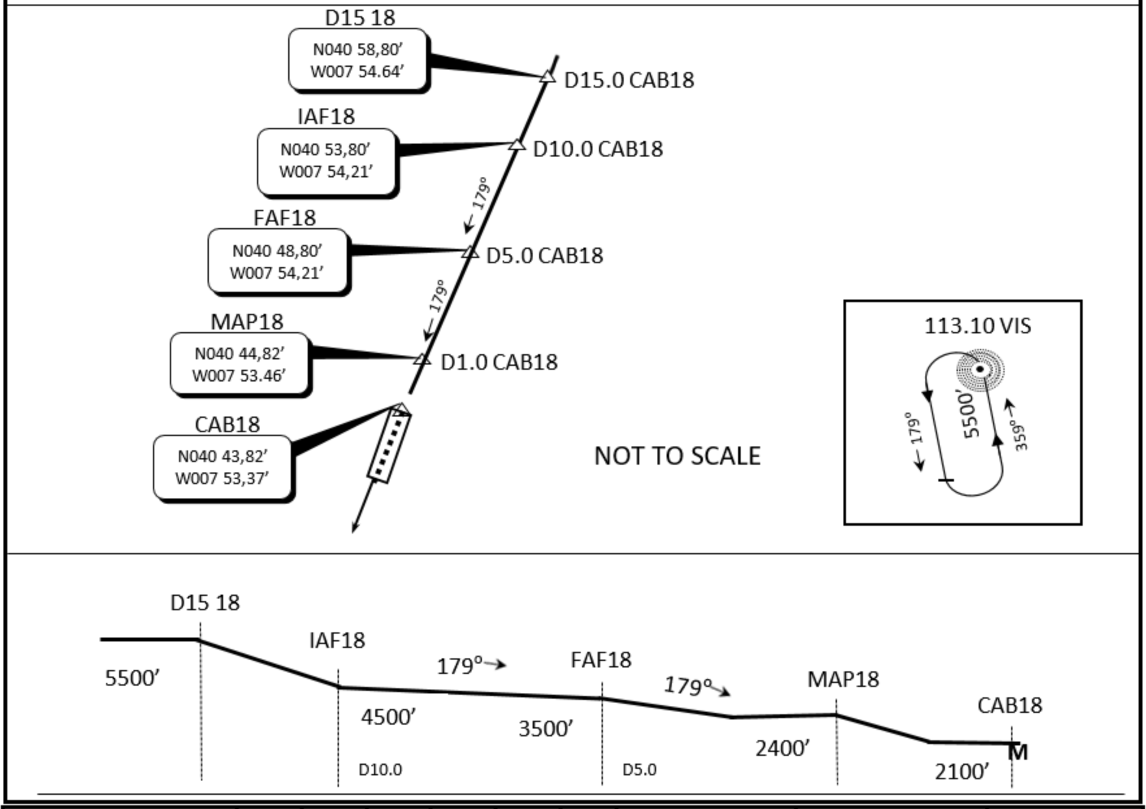
After comparing both systems, their efficiency, longevity, and integrity it was decided to only elaborate GBAS (GLS) approach charts, since it offers better precision information and flexibility at a relatively cheaper cost, compared to ILS. To elaborate these charts, besides analysing information existent in the aircraft operations document and in Annex 4 from ICAO, existing GNNS approach charts from the airfield (for training only purposes) served as a baseline for this illustration, since both charts are very similar (with the only difference being that GLS requires to select a specific channel as opposed to ILS necessary frequency). This similarity happens because the only thing GLS does is amplifying the GNSS information and signal in the approach phase by using a ground station. Knowing this, two charts were designed, one for each runway, as shown in figures 4.4 and 4.5. The software utilised was Microsoft Word.

VISEU, PORTUGAL GLS Rwy18

LPVZ

Viseu AFIS 122.70	LISBON Militar 130.90	LISBON Control 132.30	PORTO (APP) 121.10	VILA REAL AFIS 122.90	5500' 25NM
GLS	Final Approach Course **179°**	Minimum Alt D7.0 4000' (1940')	MDA(H) 2400' (340')	Apt Elev 2061' RWY 2060'	
MISSED APPROACH: Climb STRAIGHT AHED until 5500'. Turn inbound to VIS and hold. Contact ATC					MSA Apt

Alt Set: hPa	**Rwy Elev: 2060'**	**Tans level: By ATC**	**Trans alt 6000'**



Gnd speed-Kts	80	100	120	140	150	160		5500' ↑	VIS HOLD
Descent Gradient 3.2%	490	610	730	850	910	970			

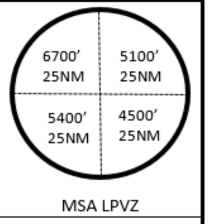
STRAIGHT-IN LANDING RWY 18	**CIRCLING TO LAND OCA (H)**		
	Cat.	EAST	WEST
NOTE: REACHING IAF18 WITH 4500' GEAR DOWN; FLAPS 1 120 KTS IAS In approach to this runway, shouldn't fly below 2400' without passing the phone antenna in the thread of the runway.	**A**	2750'(689')	2750'(689')
	B	2750'(689')	2750'(689')

Figure 4.4. GLS approach chart for runway 18

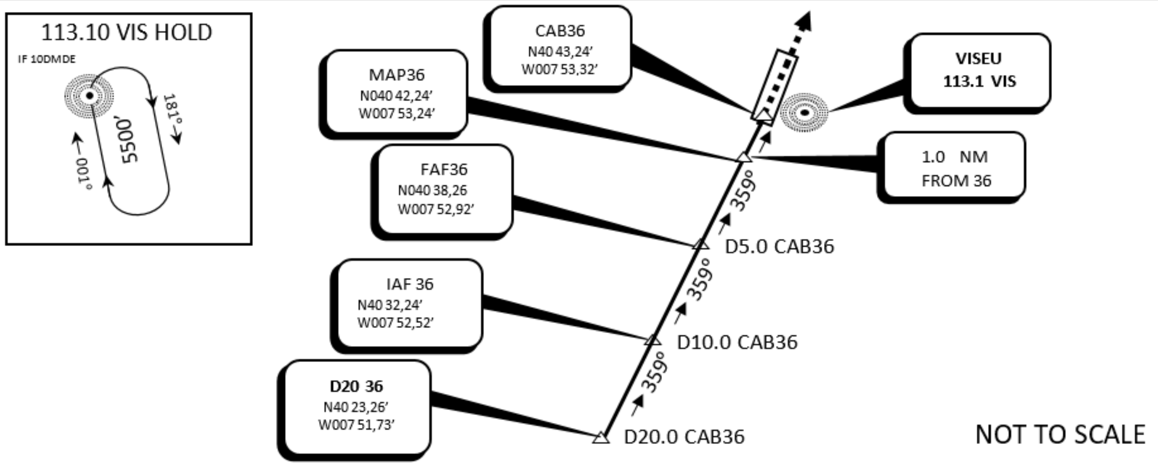
VISEU, PORTUGAL
LPVZ

GLS Rwy36

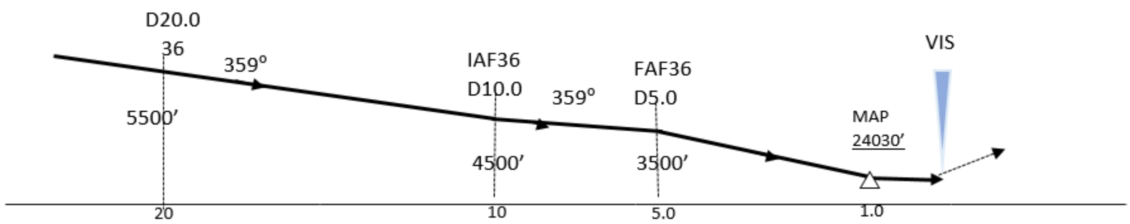
Viseu AFIS 122.70	LISBON Militar 130.90	LISBON Control 132.30	PORTO (APP) 121.10	VILA REAL AFIS 122.90
GLS	Final Approach Crs **359º**	Minimum Alt D20.0 VIS 5500’	MDA(H) 2430' (369’)	Apt Elev 2061' RWY 2061'
MISSED APPROACH: Climb STRAIGHT AHED until 4DME. Turn LEFT to VIS, climbing to 5500’ and hold.				



Alt Set: hPa **Rwy Elev: 2061'** **Tans level: By ATC** **Trans alt 5000'**



VIS DME	20.0	10.0	05.0	1.0	MAP	
ALTITUDE (HAT)	5500’	4500’	3500’	2600’	2430’	



Gnd speed-Kts	80	100	120	140	160	180
Descent Gradient 4.8% Descent Angle2,8º	490	610	730	850	910	970
FAF to MAP	3’	2.25’	2’	1.45’	1.30’	1.20’

3000'	VIS 113,10 LT

STRAIGHT-IN LANDING RWY 36

CIRCLING TO LAND OCA (H)		
Cat.	EAST	WEST
A	2930’	2930’
B	3090’	3250’

Figure 4.5. GLS approach chart for runway 36

4.6. Conclusion

As it was observed, not only the movements in the airfield have been increasing in the past years (and expected to increase even more, given the implementation of a flight school as well as new maintenance unities and other courses) but also the price of the taxes collected are expected to increase, despite the large number of exemptions that the aerodrome is subject to (i.e. its aeroclub and the Portuguese Airforce). Knowing that a European Project can fund about 80% of the investment done, a study to evaluate the economic balance of the airfield was done, and it was determined that a GLS implementation would be the better option, starting to be profitable for the airfield by the end of 2025.

From a technical point of view, a GBAS landing system would bring the most advantages in comparison to traditional ILS. Not only it's simpler to install, but also because one single GBAS station can support multiple runways ends, reducing the number of systems at the airfield. Another very important aspect is that a GBAS CAT I system can easily be upgraded to a CAT II/III, which could end up being very useful for the airfield if required in future times. In economic terms, a GLS also ends up being the better option in comparison with the ILS, presenting fewer maintenance needs and lower maintenance and operating costs. As opposed to an ILS, possible future modifications to permit CAT II and CAT III operations wouldn’t result in an increase in the operating costs in the GBAS facility, whatever are its capabilities. For all these reasons, only GLS approach charts were designed.

Chapter 5 - Conclusion

5.1. Dissertation synthesis

The first chapter of this thesis is a brief introduction to which flight phase most aeronautical accidents and incidents occur and how approaching systems can act as a vital part in reducing those occurrences. The majority happen to occur in the approach and landing phase.

The second chapter includes a literature review on regional airfields and radio aids. Inside the regional airfields, we discuss its definition, as well as the concepts of Catchment area and the economic impact they have. Inside the radios aids, we analysed some of the best options regarding the approach systems. This equipment is divided into precision and non-precision, based on the information they provide. This literature review was extended to feasibility studies, which are crucial analysis tools to weigh the pros and cons of a proposed system or idea.

The case study, incorporating the third chapter of the dissertation, is Viseu airfield. In this chapter, there is a characterization of this infrastructure, the meteorological context where it is inserted, its catchment area and the economic impact it produces on the region. Inquiries to the stakeholders were made to facilitate the analysis of these aspects. The development of Viseu as a region was studied and movements forecast for the aerodrome were performed. Different approach systems were analysed and two of them were selected to be compared.

The fourth chapter brings us to an analysis of the results obtained from the previous chapter. This discussion includes analysis of the development of the region of Viseu and a review on the answers from the inquiries previously distributed, as a way to help to measure the importance and impact of Viseu airfield as well as the extent of its catchment area. Finally, the feasibility studies, regarding the possible implementation of two different approach systems in the aerodrome. Technical specifications and prices of the equipment were compared, the revenue from the charged fees was calculated and GBAS was found as the better option. GLS approach charts were then elaborated.

5.2. Final considerations

The main goal of this work was to expose the importance of Viseu aerodrome, as a driver for its region’s development, and to determine to what extent the implementation of a particular approach system in the aerodrome is viable, by analysing its impact, especially in the economic field (overall cost needed). However, in the economic section, some difficulties were found, namely the existence of a limited range of values for the movements and taxes on the aerodrome, even though trustworthy data on this matter was obtained. For this reason, the work had to be directed in a more technical view, where the help from specialized technicians in the airfield took a major part in the studies. The answers from the companies for the survey section also ended up being more delayed and some of them not possible to obtain. The equipment's associated costs also had a wide range of prices, and the most suitable ones had to be chosen. Despite this, the data collected was enough to perform a steady and balanced study on the airfield and on the impact possible changes would produce. The catchment area of the airfield was also one of the highly controversial aspects of the study because unlike the big airports of Portugal, where ANA defines its catchment area by travel time, the same doesn't happen for Viseu aerodrome, where an estimation of this area had to be made.

Thus, remembering the objectives pointed in chapter 1, and in summary:

- Analysing and studying the different approach systems, as a way to improve safety levels – Completely Achieved (see chapter 2);
- Exposing the impact of this infrastructure (Viseu airfield) as a driver for the airfield development and demand growth – Completely Achieved (see chapter 3);
- Understanding in which conditions and to what extent the implementation of a given approach system is viable, by performing feasibility studies – Completely Achieved (see chapter 4);
- Analysing the results and verifying the impact this decision would have in the airfield and also within its region, in the social and economic fields – Partially achieved. The impact in the airfield was verified but not within its region (see chapter 4).

Overall, we consider this project to be a successful one since it was done with the maximum possible rigor and the results obtained were what we were expecting, despite some difficulties in defining the criteria to evaluate the economic feasibility section.

5.3. Perspectives for future research

As can be recognized, the air transportation scene has been growing until the date, and the expectations are for it to keep growing even more. The contributions of airports and regional airfields are essential in supporting the development of the aviation industry.

During the development of this dissertation, various topics were recognized as useful to implement in future research works. Specifying the case of Viseu airfield, the next steps of this work should be directed towards:

- Inquire a greater number of companies, not only in the region of Viseu but also in neighbouring regions, obtaining a greater number of answers;

- Obtain a greater sample size for the airfield movements over the years;

- Try to obtain exact values for the revenue from the airfield taxes, each year, as well as adding other types of charged fees atop from landing, and thus obtaining more realistic results from the forecasts;
- Analyse and compare a wider variety of approach systems, especially the most recent ones;
- Analyse success cases after a system implementation of this type in similar airfields and verify the impact, essentially in the increase of movements it produced.

Therefore, the goal is to bring increased safety to every aeronautical infrastructure as possible, but keeping in mind that the expensiveness of some equipment can't always be matched by some airports or airfields, and therefore cheaper and less effective solutions should be taken in these cases.

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Annex A - Survey

A proximidade do Aeródromo de Viseu como fator de localização de empresas e de desenvolvimento de negócios

Este questionário foi desenvolvido no seio do Núcleo de Investigação em Transportes, do Departamento de Ciências Aeroespaciais da Universidade da Beira Interior, com o principal objetivo de avaliar o *Hinterland* (Área de Influência) do Aeródromo Gonçalves Lobato (Viseu), relativamente aos Aeroportos Nacionais do Porto e de Lisboa. Trata-se de um questionário no âmbito de uma tese de Mestrado em Engenharia Aeronáutica que está a ser desenvolvida por mim, Pedro Manuel Pimenta da Silva Oliveira, sob supervisão científica do Professor Jorge Miguel dos Reis Silva, e do Comandante Paulo Alexandre Ramos de Figueiredo Soares.

Estima-se que o preenchimento deste questionário demore sensivelmente 10 minutos. Os dados são confidenciais e poderão ser eliminados, a pedido.

Grupo A: Caraterização da Empresa

Este grupo destina-se à Caraterização da sua Empresa

A1. Nome:
A2. Localidade:
A3. Setor de Atividade (CAE):

Grupo B: Ligação ao Aeroporto ou Aeródromo

Utilização do Aeroporto ou Aeródromo

B1. Nos últimos 12 meses a sua Empresa utilizou algum Aeroporto ou Aeródromo para transporte de Carga ou Passageiros?

☐ Sim
☐ Não utilizou Aeroporto ou Aeródromo nos últimos 12 meses

B2. Selecione os fatores que levariam a sua empresa, no futuro, a utilizar um Aeroporto ou Aeródromo como parceiro estratégico nas suas relações comerciais:

☐ Acessibilidade à Rede de Estradas
☐ Proximidade do Aeroporto ou Aeródromo
☐ Destinos Disponíveis
☐ Parceiros de Negócios Internacionais

☐ Preços Baixos
☐ Rapidez e Segurança do Transporte
☐ Outro

Grupo C: Aeroportos ou Aeródromos Utilizados

Utilização do Aeroporto ou Aeródromo

C1. Qual o motivo da utilização do(s) Aeroporto ou Aeródromo(s)?
Para cada opção (Passageiros ou Carga) será aberto um conjunto específico de perguntas

☐ Transporte de Passageiros
☐ Transporte de Carga

Grupo D: Para o Transporte de Passageiros

Este grupo de perguntas refere-se apenas ao transporte de Passageiros

D1. Dos seguintes Aeroportos ou Aeródromos indique qual (ou quais) são utilizados pela sua Empresa, na opção de transporte de Passageiros:

☐ Aeroporto Francisco Sá Carneiro (Porto)
☐ Aeródromo Gonçalves Lobato (Viseu)
☐ Aeroporto Humberto Delgado (Lisboa)

D2. Dos seguintes Aeroportos ou Aeródromos indique qual o que mais gostaria de utilizar para a sua Empresa, na opção de transporte de Passageiros:
Para cada Aeroporto ou Aeródromo selecionado será aberto um conjunto de perguntas em separado

☐ Aeroporto Francisco Sá Carneiro (Porto)
☐ Aeródromo Gonçalves Lobato (Viseu)
☐ Aeroporto Humberto Delgado (Lisboa)
☐ Outro

D3. Qual o (outro) Aeroporto ou Aeródromo utilizado para o Transporte de Passageiros?

D4. Selecione os fatores que levaram à escolha do Aeroporto Francisco Sá Carneiro (Porto):
Se selecionar a opção "Outro" tem de fornecer uma descrição

☐ Preço dos bilhetes
☐ Destinos disponíveis
☐ Horário dos voos
☐ Existência de parque de estacionamento
☐ Preço do parque de estacionamento
☐ Tempo de viagem até ao Aeroporto
☐ Custo da viagem até ao Aeroporto
☐ Proximidade geográfica
☐ Rapidez nos voos
☐ Rapidez na entrega/recolha das bagagens
☐ Rapidez de Check-In
☐ Rapidez dos procedimentos de Segurança
☐ Rapidez em chegar até à Porta de Embarque
☐ Outro

D5. Qual a frequência com que a sua Empresa utiliza o Aeroporto Francisco Sá Carneiro (Porto)?
Se selecionar a opção "Outro" tem de fornecer uma descrição

☐ Diária
☐ Semanal
☐ Mensal
☐ Trimestral
☐ Semestral
☐ Anual
☐ Outro

D6. Qual o meio de transporte utilizado para chegar até ao Aeroporto Francisco Sá Carneiro (Porto)?
Se selecionar a opção "Outro" tem de fornecer uma descrição

☐ Carro (viatura própria)
☐ Carro (viatura da empresa)
☐ Carro alugado
☐ Táxi
☐ Comboio
☐ Autocarro
☐ Transfer (shuttle)
☐ Outro

D7. Selecione os fatores que levaram à escolha do Aeródromo Gonçalves Lobato (Viseu):

Se selecionar a opção "Outro" tem de fornecer uma descrição

☐ Preço dos bilhetes
☐ Destinos disponíveis
☐ Horário dos voos
☐ Existência de parque de estacionamento
☐ Preço do parque de estacionamento
☐ Tempo de viagem até ao Aeródromo
☐ Custo da viagem até ao Aeródromo
☐ Proximidade geográfica
☐ Rapidez nos voos
☐ Rapidez na entrega/recolha das bagagens
☐ Rapidez de Check-In
☐ Rapidez dos procedimentos de Segurança
☐ Rapidez em chegar até à Porta de Embarque
☐ Outro

D8. Qual a frequência com que a sua Empresa utiliza o Aeródromo Gonçalves Lobato (Viseu)?

Se selecionar a opção "Outro" tem de fornecer uma descrição

☐ Diária
☐ Semanal
☐ Mensal
☐ Trimestral
☐ Semestral
☐ Anual
☐ Outro

D9. Qual o meio de transporte utilizado para chegar até ao Aeródromo Gonçalves Lobato (Viseu)?

Se selecionar a opção "Outro" tem de fornecer uma descrição

☐ Carro (viatura própria)
☐ Carro (viatura da empresa)
☐ Carro alugado
☐ Táxi
☐ Comboio
☐ Autocarro
☐ Transfer (shuttle)

☐ Outro

D10. Selecione os fatores que levaram à escolha desse (outro) Aeroporto ou Aeródromo:
Se selecionar a opção "Outro" tem de fornecer uma descrição

☐ Preço dos bilhetes
☐ Destinos disponíveis
☐ Horário dos voos
☐ Existência de parque de estacionamento
☐ Preço do parque de estacionamento
☐ Tempo de viagem até ao Aeroporto ou Aeródromo
☐ Custo da viagem até ao Aeroporto ou Aeródromo
☐ Proximidade geográfica
☐ Rapidez nos voos
☐ Rapidez na entrega/recolha das bagagens
☐ Rapidez de Check-In
☐ Rapidez dos procedimentos de Segurança
☐ Rapidez em chegar até à Porta de Embarque
☐ Outro

D11. Qual a frequência com que a sua Empresa utiliza esse (outro) Aeroporto ou Aeródromo?
Se selecionar a opção "Outro" tem de fornecer uma descrição

☐ Diária
☐ Semanal
☐ Mensal
☐ Trimestral
☐ Semestral
☐ Anual
☐ Outro

D12. Qual o meio de transporte utilizado para chegar até esse (outro) Aeroporto ou Aeródromo?
Se selecionar a opção "Outro" tem de fornecer uma descrição

☐ Carro (viatura própria)
☐ Carro (viatura da empresa)
☐ Carro alugado
☐ Táxi

☐ Comboio

☐ Autocarro

☐ Transfer (shuttle)

☐ Outro

D13. Selecione os fatores que levaram à escolha do Aeroporto Humberto Delgado (Lisboa):

Se selecionar a opção "Outro" tem de fornecer uma descrição

☐ Preço dos bilhetes

☐ Destinos disponíveis

☐ Horário dos voos

☐ Existência de parque de estacionamento

☐ Preço do parque de estacionamento

☐ Tempo de viagem até ao Aeroporto

☐ Custo da viagem até ao Aeroporto

☐ Proximidade geográfica

☐ Rapidez nos voos

☐ Rapidez na entrega/recolha das bagagens

☐ Rapidez de Check-In

☐ Rapidez dos procedimentos de Segurança

☐ Rapidez em chegar até à Porta de Embarque

☐ Outro

D14. Qual a frequência com que a sua Empresa utiliza o Aeroporto Humberto Delgado (Lisboa)?

Se selecionar a opção "Outro" tem de fornecer uma descrição

☐ Diária

☐ Semanal

☐ Mensal

☐ Trimestral

☐ Semestral

☐ Anual

☐ Outro

D15. Qual o meio de transporte utilizado para chegar até ao Aeroporto Humberto Delgado (Lisboa)?

Se selecionar a opção "Outro" tem de fornecer uma descrição

☐ Carro (viatura própria)

☐ Carro (viatura da empresa)

☐ Carro alugado

☐ Táxi

☐ Comboio

☐ Autocarro

☐ Transfer (shuttle)

☐ Outro

Grupo E: Para o Transporte de Carga

Este grupo de perguntas refere-se apenas ao Transporte de Carga

E1. Dos seguintes Aeroportos ou Aeródromos, indique quais os que mais utiliza para a sua Empresa, na opção de transporte de Carga:

☐ Aeroporto Francisco Sá Carneiro (Porto)

☐ Aeródromo Gonçalves Lobato (Viseu)

☐ Aeroporto Humberto Delgado (Lisboa)

☐ Nenhum deles

E2. Dos seguintes Aeroportos ou Aeródromos, indique qual o que mais gostaria de utilizar para a sua Empresa, na opção de transporte de Carga:

Para cada Aeroporto ou Aeródromo selecionado será aberto um conjunto de perguntas em separado

☐ Aeroporto Francisco Sá Carneiro (Porto)

☐ Aeródromo Gonçalves Lobato (Viseu)

☐ Aeroporto Humberto Delgado (Lisboa)

☐ Outro

E3. Qual o (outro) Aeroporto ou Aeródromo utilizado para o Transporte de Carga?

E4. Selecione os fatores que levaram à escolha do Aeroporto Francisco Sá Carneiro (Porto):

Se selecionar a opção "Outro" tem de fornecer uma descrição

☐ Localização Geográfica

☐ Atendimento ao Cliente

☐ Capacidade de Armazenamento do Aeroporto

☐ Custo do Serviço

☐ Tempo de Ligação (Entrega)

☐ Destinos disponíveis

☐ Existência de Serviços Personalizados

☐ Eficiência Alfandegária

☐ Armazenamento Moderno e Funcional

☐ Seguimento da Carga

☐ Rapidez no Processamento

☐ Baixo nível de Danos

☐ Diversidade de Serviços

☐ Outro

E5. Qual a frequência com que a sua Empresa utiliza o Aeroporto Francisco Sá Carneiro (Porto)?

Se selecionar a opção "Outro" tem de fornecer uma descrição

☐ Diária

☐ Semanal

☐ Mensal

☐ Trimestral

☐ Semestral

☐ Anual

☐ Outro

E6. Selecione os fatores que levaram à escolha do Aeródromo Gonçalves Lobato (Viseu):

Se selecionar a opção "Outro" tem de fornecer uma descrição

☐ Localização Geográfica

☐ Atendimento ao Cliente

☐ Capacidade de Armazenamento do Aeródromo

☐ Custo do Serviço

☐ Tempo de Ligação (Entrega)

☐ Destinos disponíveis

☐ Existência de Serviços Personalizados

☐ Eficiência Alfandegária

☐ Armazenamento Moderno e Funcional

☐ Seguimento da Carga

☐ Rapidez no Processamento

☐ Baixo nível de Danos

☐ Diversidade de Serviços

☐ Outro

E7. Qual a frequência com que a sua Empresa utiliza o Aeródromo Gonçalves Lobato (Viseu)?

Se selecionar a opção "Outro" tem de fornecer uma descrição

☐ Diária
☐ Semanal
☐ Mensal
☐ Trimestral
☐ Semestral
☐ Anual
☐ Outro

E8. Selecione os fatores que levaram à escolha do Aeroporto Humberto Delgado (Lisboa):

Se selecionar a opção "Outro" tem de fornecer uma descrição

☐ Localização Geográfica
☐ Atendimento ao Cliente
☐ Capacidade de Armazenamento do Aeroporto
☐ Custo do Serviço
☐ Tempo de Ligação (Entrega)
☐ Destinos disponíveis
☐ Existência de Serviços Personalizados
☐ Eficiência Alfandegária
☐ Armazenamento Moderno e Funcional
☐ Seguimento da Carga
☐ Rapidez no Processamento
☐ Baixo nível de Danos
☐ Diversidade de Serviços
☐ Outro

E9. Qual a frequência com que a sua Empresa utiliza o Aeroporto Humberto Delgado (Lisboa)?

Se selecionar a opção "Outro" tem de fornecer uma descrição

☐ Diária
☐ Semanal
☐ Mensal
☐ Trimestral
☐ Semestral
☐ Anual
☐ Outro

E10. Selecione os fatores que levaram à escolha desse (outro) Aeroporto ou Aeródromo:

Se selecionar a opção "Outro" tem de fornecer uma descrição

☐ Localização Geográfica
☐ Atendimento ao Cliente
☐ Capacidade de Armazenamento do Aeroporto ou Aeródromo
☐ Custo do Serviço
☐ Tempo de Ligação (Entrega)
☐ Destinos disponíveis
☐ Existência de Serviços Personalizados
☐ Eficiência Alfandegária
☐ Armazenamento Moderno e Funcional
☐ Seguimento da Carga
☐ Rapidez no Processamento
☐ Baixo nível de Danos
☐ Diversidade de Serviços
☐ Outro

E11. Qual a frequência com que a sua Empresa utiliza esse (outro) Aeroporto ou Aeródromo?
Se selecionar a opção "Outro" tem de fornecer uma descrição

☐ Diária
☐ Semanal
☐ Mensal
☐ Trimestral
☐ Semestral
☐ Anual
☐ Outro

Grupo F: Fatores de Localização

Fatores de Localização

F1. Quais dos seguintes fatores tiveram influência na localização atual da sua empresa?
Selecione pelo menos uma resposta
Se selecionar a opção "Outro" tem de fornecer uma descrição

☐ Proximidade de Clientes
☐ Proximidade de Fornecedores
☐ Proximidade do Aeroporto ou Aeródromo
☐ Acessibilidade à Rede de Estradas
☐ Acessibilidade Internacional

☐ Área com elevada Densidade Populacional
☐ Mão-de-obra mais Barata
☐ Mão-de-obra Qualificada
☐ Regime Fiscal favorável
☐ Serviços Logísticos disponíveis
☐ Perfil Económico da Região
☐ Outro(s):

Grupo G: Influência do Aeroporto ou Aeródromo na Localização das Empresas

Influência do Aeroporto ou Aeródromo na Localização das Empresas

G1. Classifique qual a influência que a Localização do Aeroporto ou Aeródromo teve sobre a Localização da sua Empresa:

☐ O Aeroporto ou Aeródromo não teve qualquer influência
☐ O Aeroporto ou Aeródromo teve alguma influência
☐ O Aeroporto ou Aeródromo teve muita influência
☐ A proximidade ao Aeroporto ou Aeródromo foi decisiva na localização

Grupo H: Benefícios das Empresas

Benefícios das Empresas

H1. Quais os Benefícios para a sua empresa decorrentes da utilização do Aeroporto ou Aeródromo?

Se selecionar a opção "Outro" tem de fornecer uma descrição

☐ Aumento do mercado (clientes)
☐ Aumento de Parcerias (fornecedores, distribuidores)
☐ Mais Viagens de Negócios (Feiras, Congressos, Exposições)
☐ Aumento do Volume de Negócios
☐ Redução dos Custos (Preços Competitivos)
☐ Maior Facilidade nas Importações/Exportações
☐ Internacionalização da Empresa
☐ Redução do tempo de Envio/Receção de Mercadorias
☐ Reputação da Empresa
☐ Outro

Grupo I: Agradecimento

I1. Obrigado pela sua disponibilidade para responder a este Questionário.

Se tiver algum comentário/sugestão poderá deixá-lo na caixa de texto logo abaixo. No caso de estar interessado em obter mais informações acerca deste estudo, deixe-nos o seu email.

Annex B - Survey results

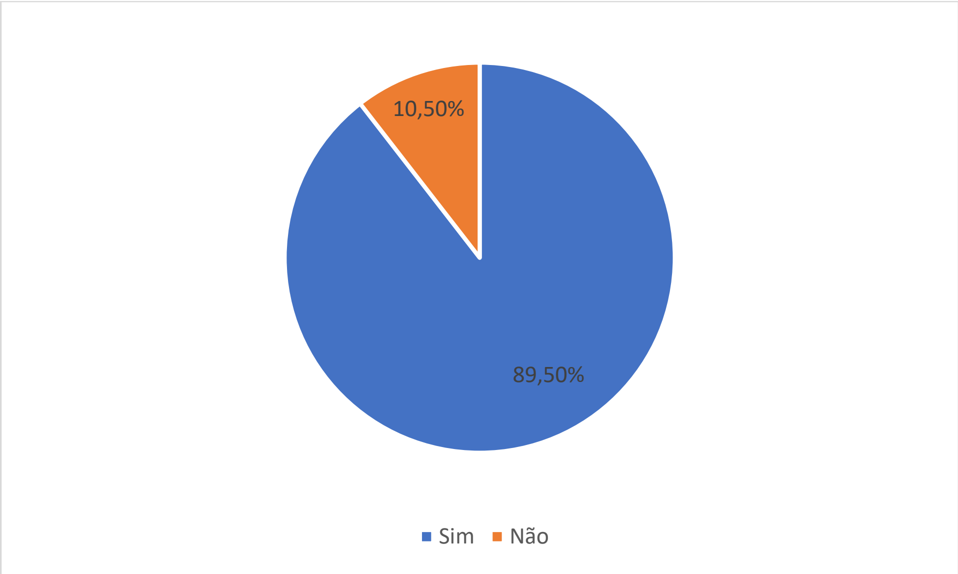

Figure B.1. Use of the airport in the last 12 months (19 answers)

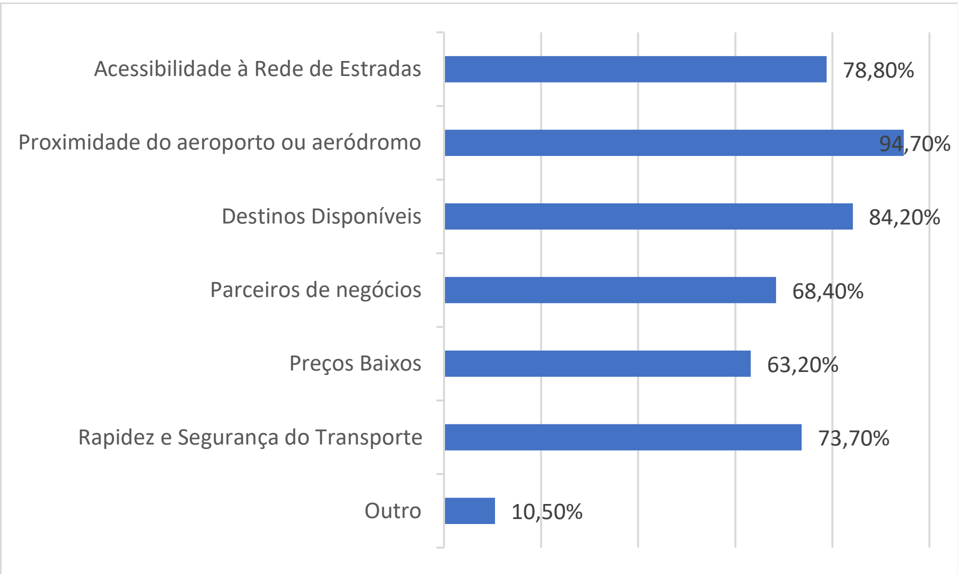

Figure B.2. Factors that would lead to the use of the airport (19 answers)

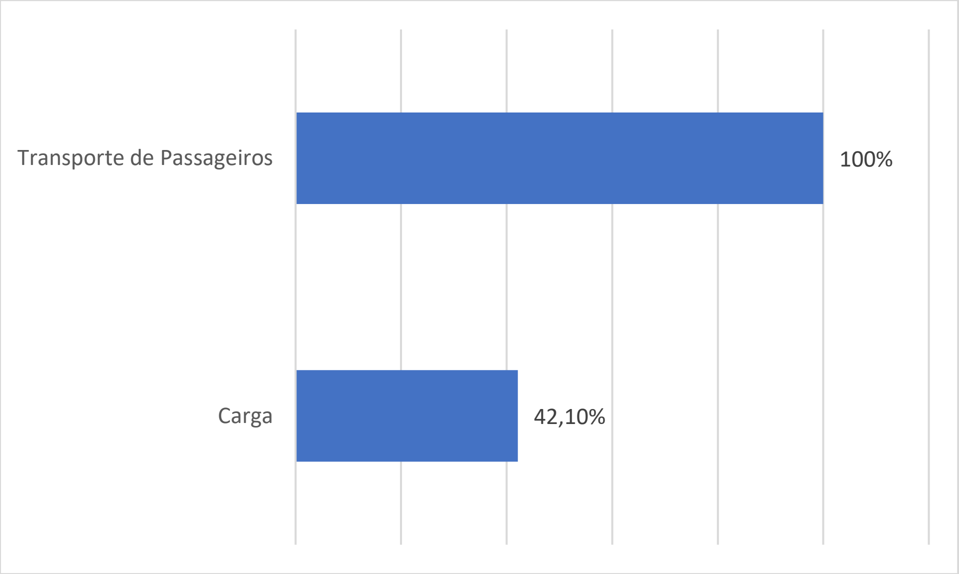

Figure B.3. The motive to use the airport (19 answers)

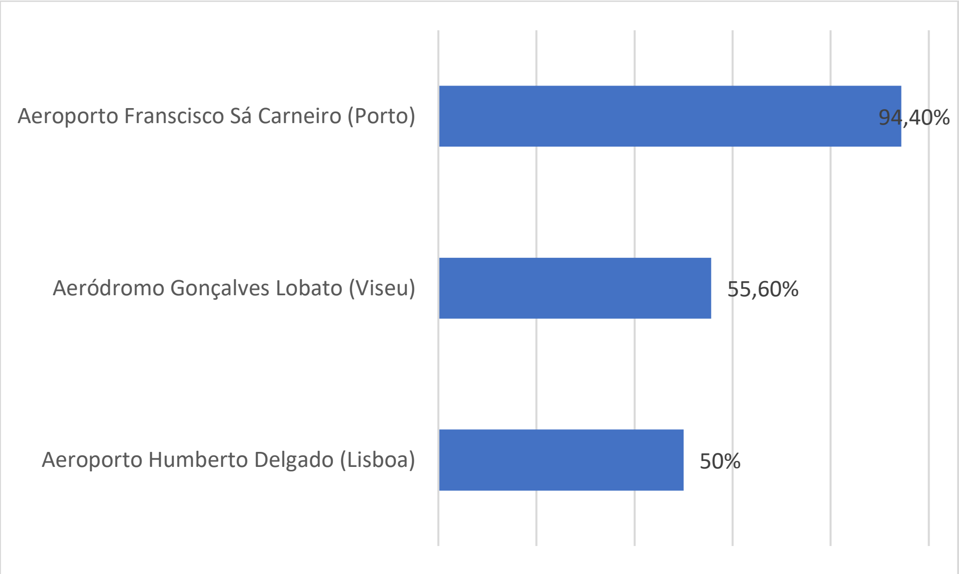

Figure B.4. Passenger airport choice (18 answers)

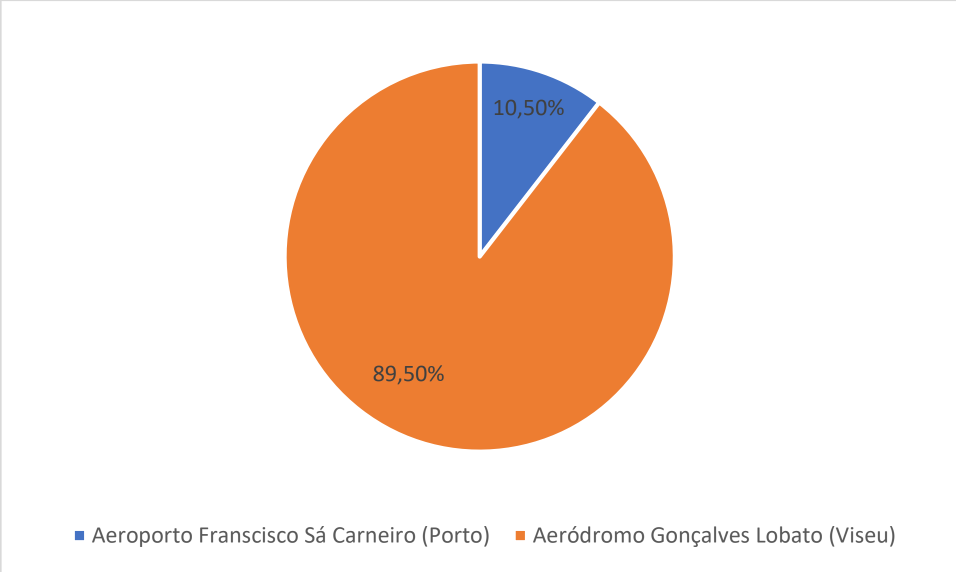

Figure B.5. Preferential passenger airport choice (19 answers)

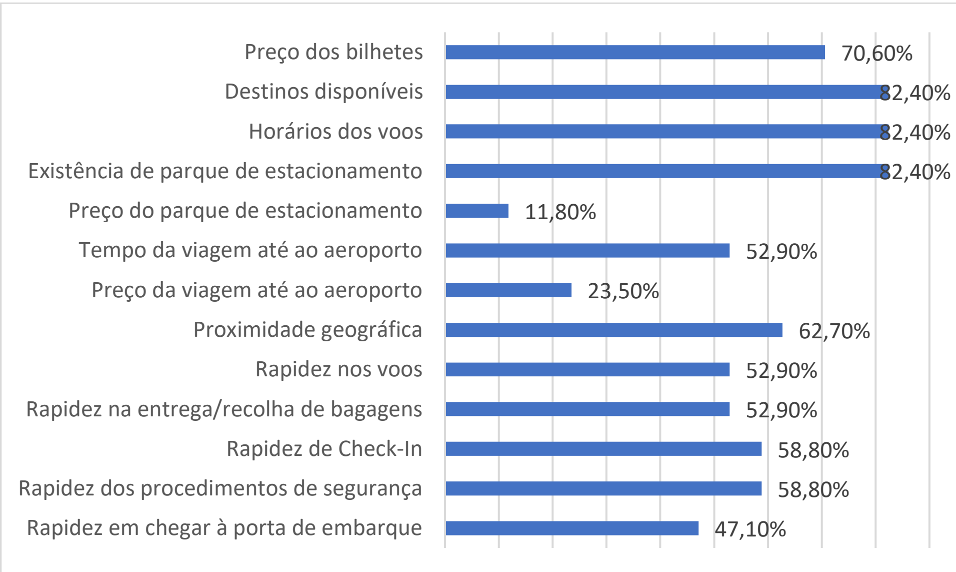

Figure B.6. Factors that would lead to greater utilization of Viseu airfield for passengers (17 answers)

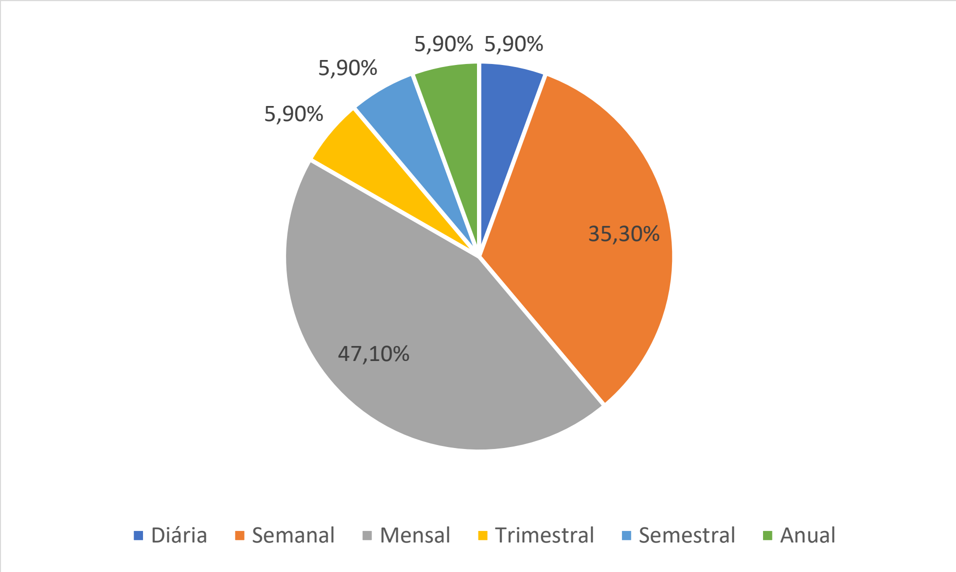

Figure B.7. Viseu airfield passengers use frequency (17 answers)

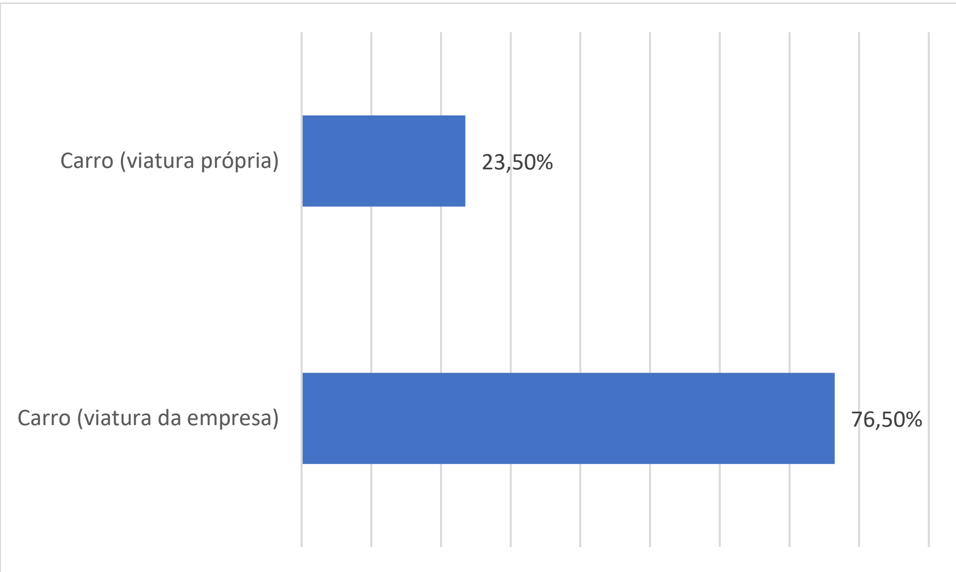

Figure B.8. Getting to Viseu airfield (17 answers)

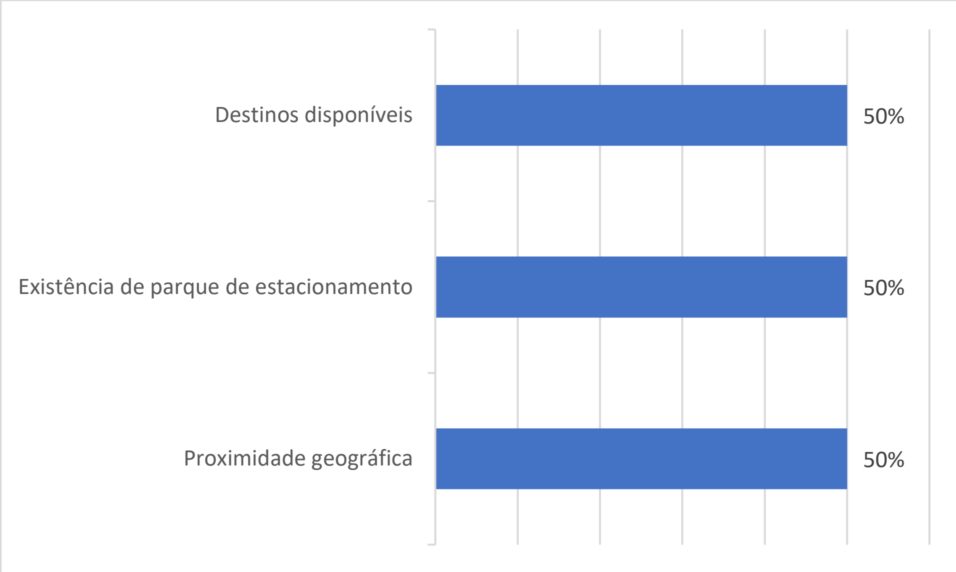

Figure B.9. Oporto airport choice factors (2 answers)

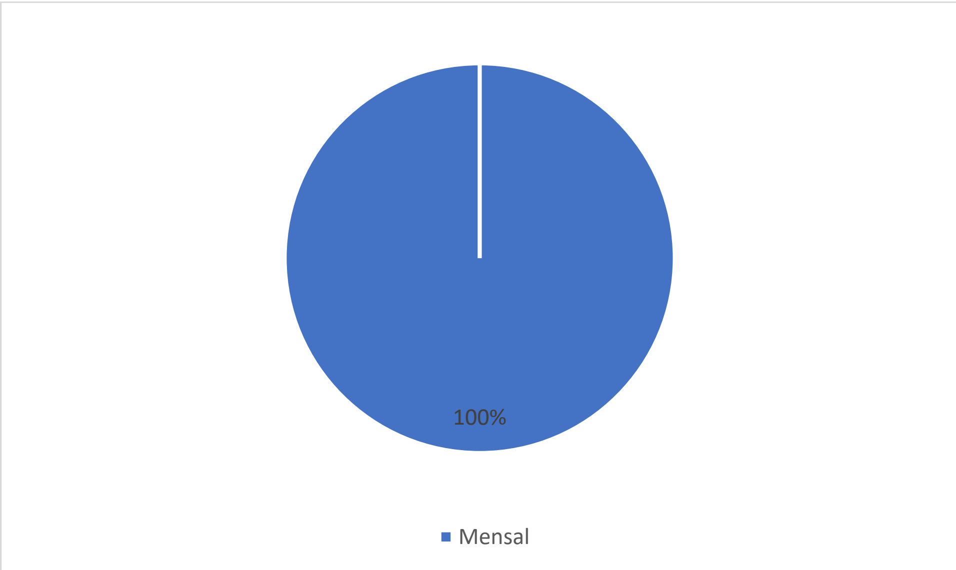

Figure B.10. Oporto airport use frequency (2 answers)

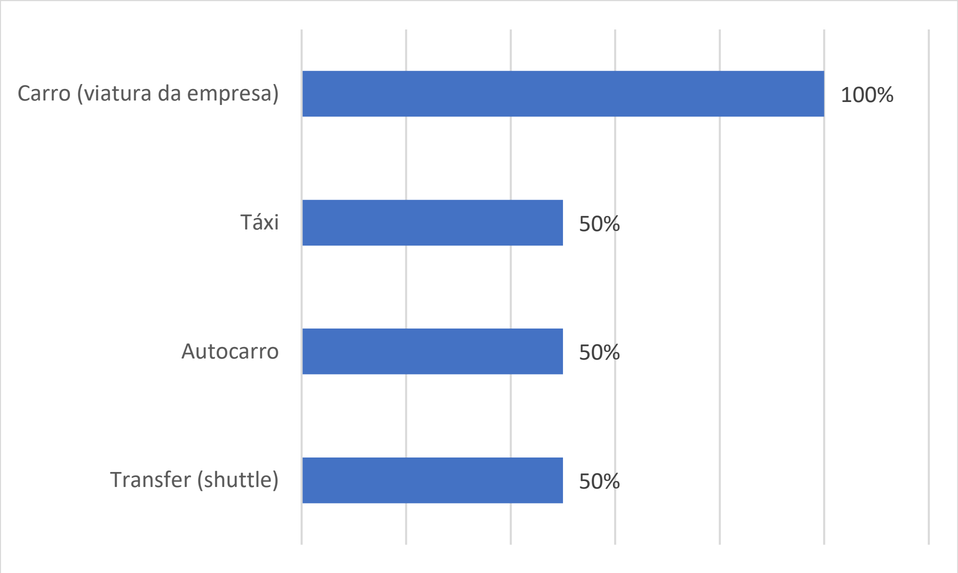

Figure B.11. Getting to Oporto airport (2 answers)

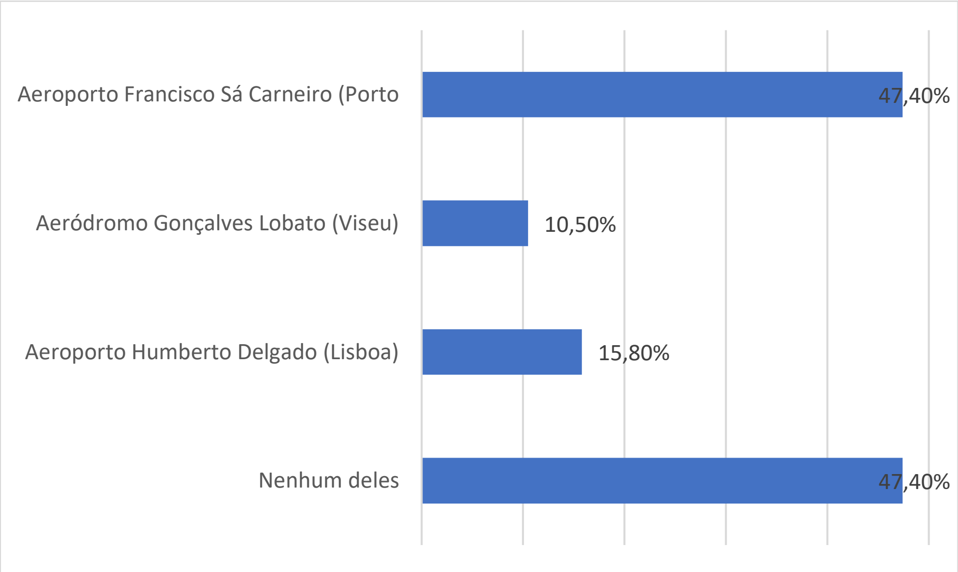

Figure B.12. Cargo airport choice (19 answers)

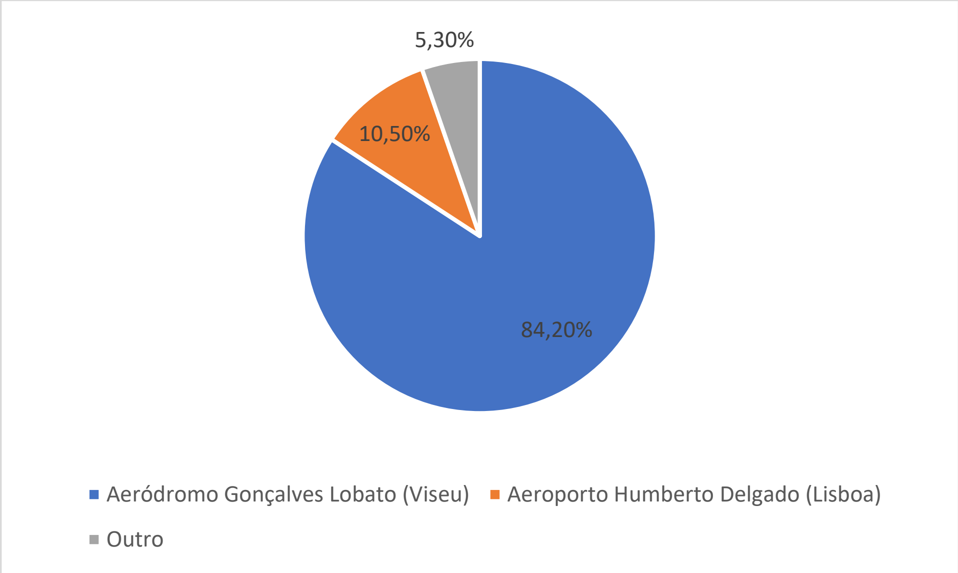

Figure B.13. Preferential cargo airport choice (19 answers)

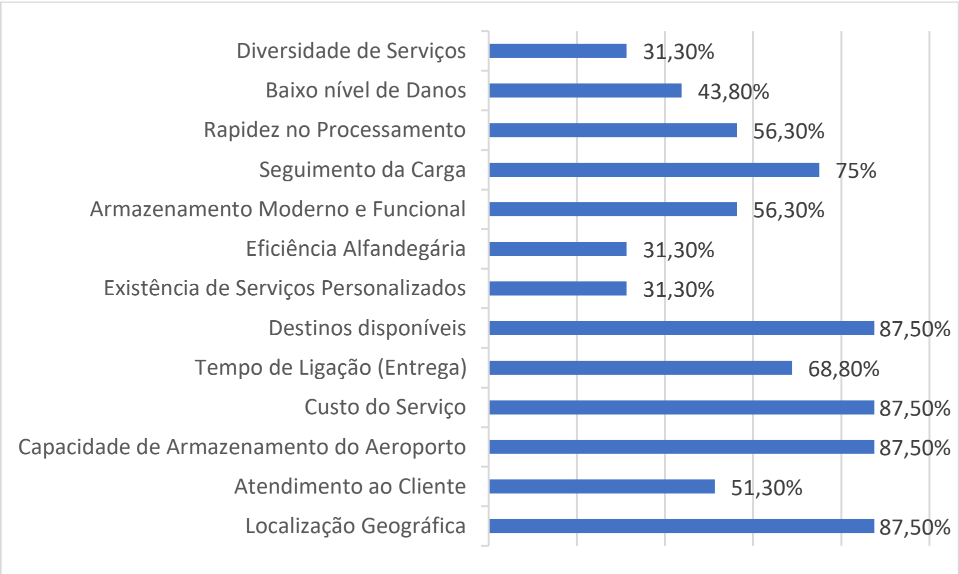

Figure B.14. Factors that would lead to greater utilization of Viseu airfield for cargo (16 answers)

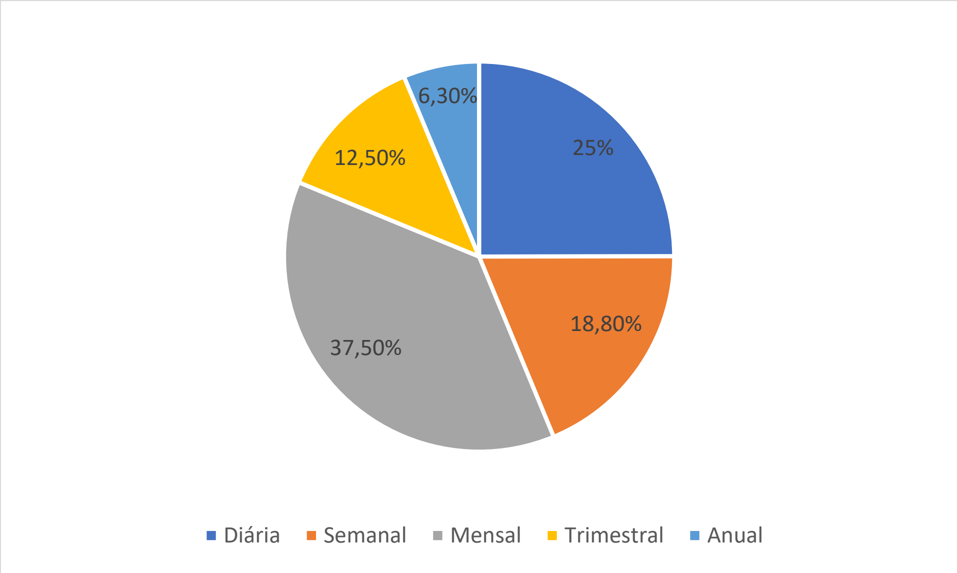

Figure B.15. Viseu airfield cargo use frequency (16 answers)

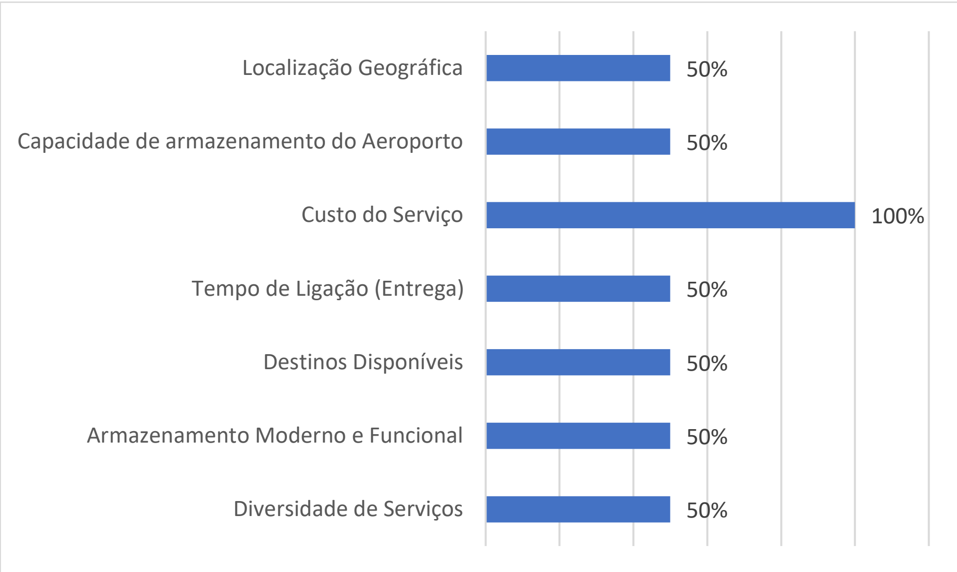

Figure B.16. Lisbon airport cargo choice factors (2 answers)

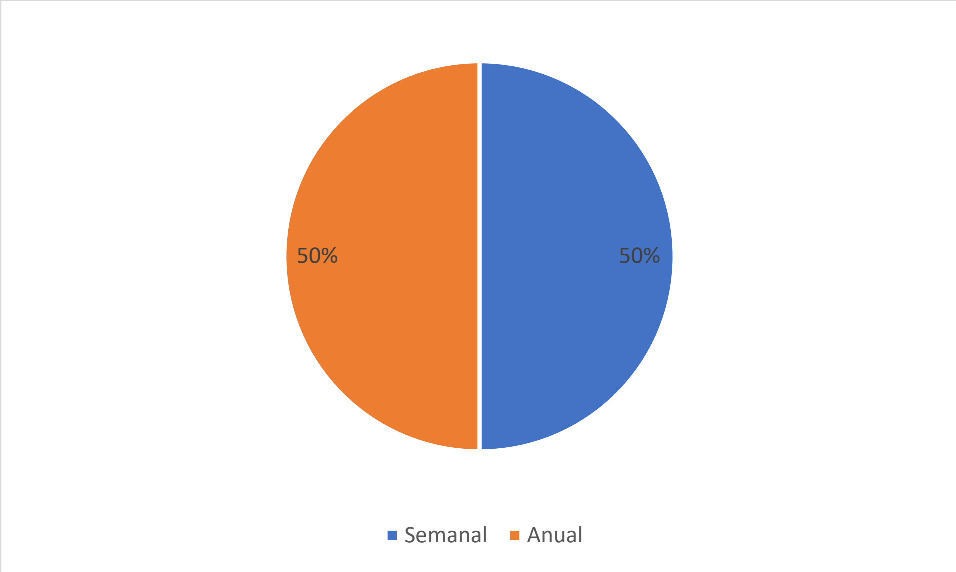

Figure B.17. Lisbon airport use frequency (2 answers)

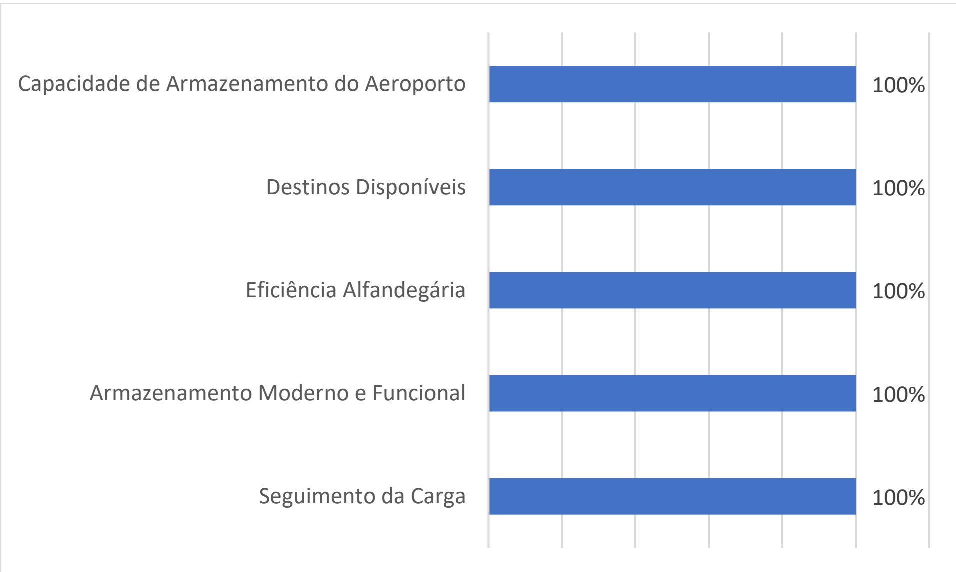

Figure B.18. Other airport cargo choice factors (1 answer)

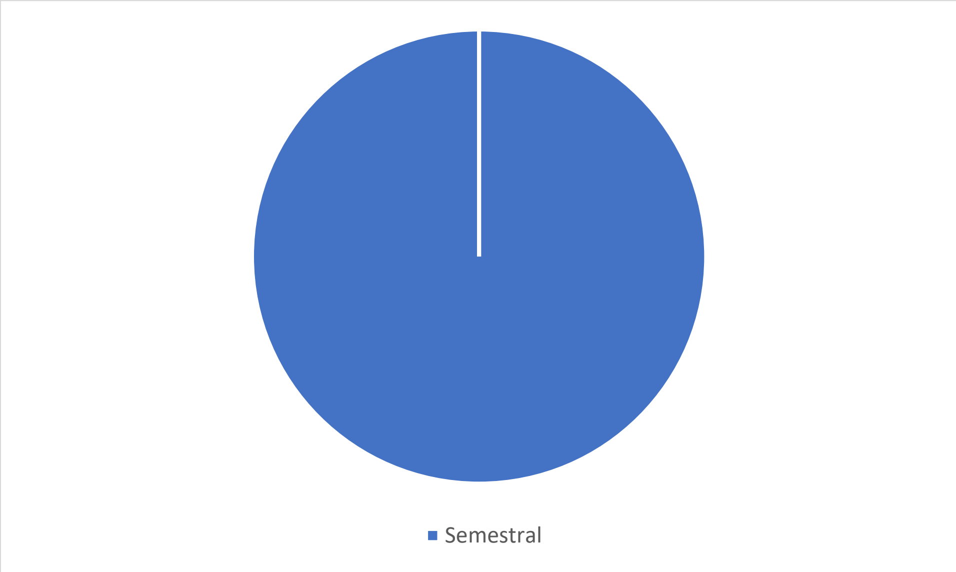

Figure B.19. Other airport use frequency (1 answer)

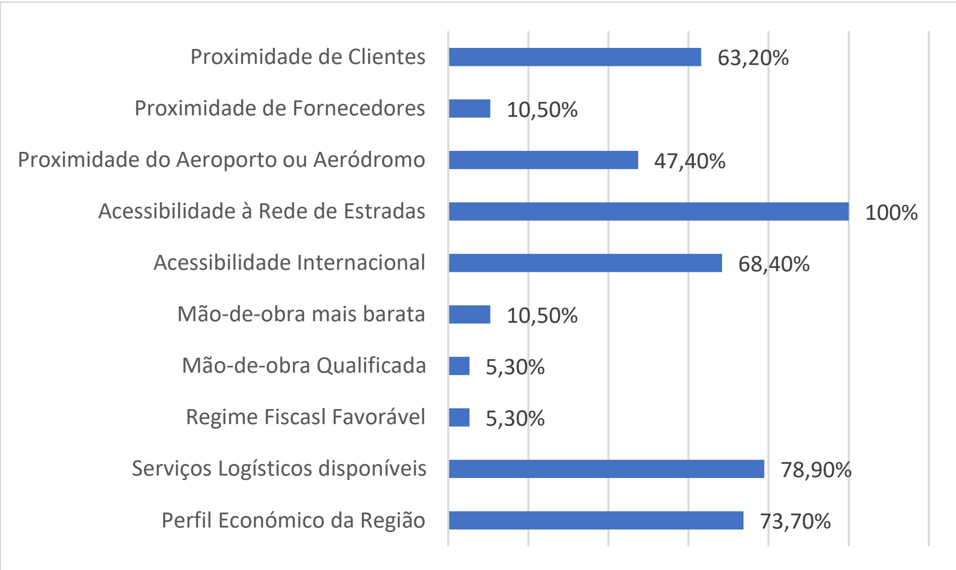

Figure B.20. Current companies' location factors (19 answers)

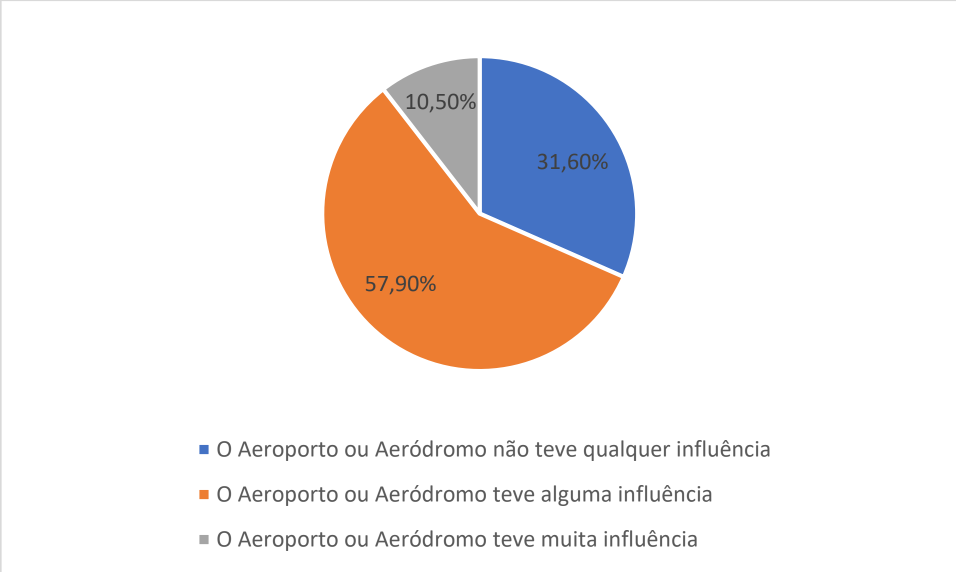

Figure B.21. Airport influence on the companies' current location (19 answers)

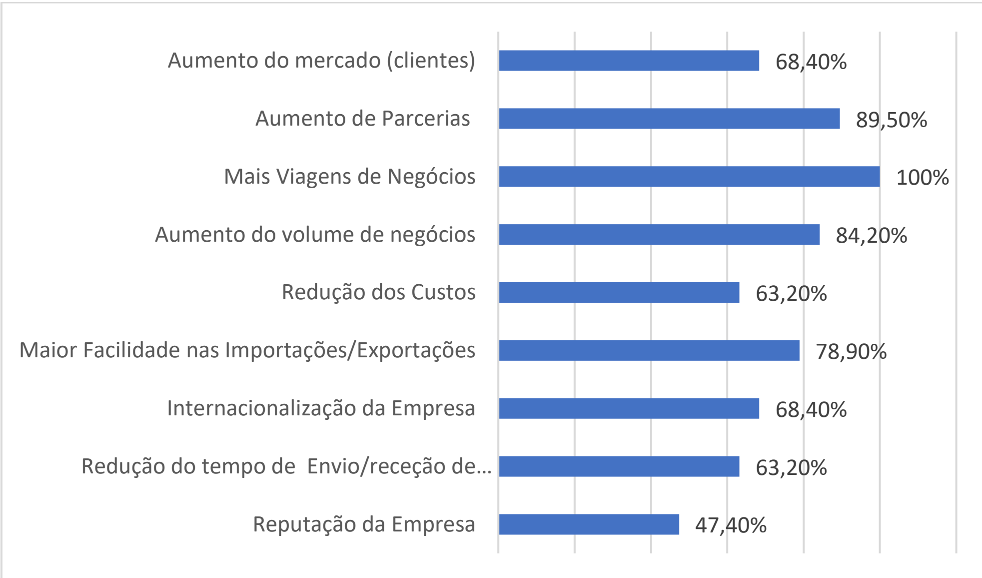

Figure B.22. Benefits from the use of the airport for the companies (19 answers)

Annex C – Scientific article to be published in Transport Problems Journal

Keywords: regional airfield, regional development, radio aids, approach systems, safety

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TECHNICAL AND ECONOMIC VIABILITY OF THE IMPLEMENTATION OF APPROACH SYSTEMS (RADIO AIDS) IN REGIONAL AIRFIELDS (VISEU AIRFIELD CASE STUDY)

Summary. The article aims to show the viability of installing a precision-based approach system in Viseu airfield, in Portugal. It analyses the airfield's evolution over time and forecasts its movements for the future, over a 10-year period. The purpose of the work is to evidence to what extent the implementation of one of these approach systems is viable, and which would be the better option for this case, from a technical and economic view. The systems analysed were ILS (Instrument Landing System) and GBAS (Ground-Based Augmentation System), both precision equipment. To better analyse the economic section, airfield taxes were reviewed and estimated to determine the period needed for the airfield to recover the investment done, allied with an 80% funding European project.

1. INTRODUCTION

Despite all the efforts made by various institutions towards aeronautical safety, accidents and incidents are likely to happen at any time and under any circumstance. At a commercial level, around half of these accidents occur during the approach and landing phases [1]. Radio aids were developed to provide pilots increased safety during flight, being requisite in modern aviation. Inside this equipment, we can find the approach systems, which operate in the approaching and landing phases of flight.

Regional airfields take a very important role in the aviation industry. Despite primarily serving short and medium-range routes inside a country, they're essential at working as congestion relievers to other nearby airports with heavy traffic. The search for regional airports and airfields has been significantly increasing over the last few decades. A 173% growth in passengers has been registered from 1993 to 2015 in Europe regional airports [2]. By 2017, global traffic surpassed the 8.2 billion mark and WATF (World Airport Traffic Forecasts) studies expect this number to double by 2034, based on a projected growth of 4,3% per year [3]. In the case of Portugal, regional air transportation isn't so significant when compared to the global scene, however, the growth is still verified, and the airfields' importance to the development of their regions is inevitable.

2. APPROACH SYSTEMS

Approach systems were developed with the main objective of increasing the safety indices in the approaching and landing phases of flight, reducing the risks inherent to its complexity. These systems can be divided into precision (course guidance and glidepath provided) and non-precision (only course guidance provided). As mitigation against CFIT (Controlled Flight into Terrain) on approach to landing, APV (Approach Procedure with Vertical guidance) systems were also adopted. Despite utilizing lateral and vertical guidance, these systems don't meet the ICAO (International Civil Aviation Organization) and FAA (Federal Aviation Administration) precision approach definitions, which apply mostly to localizer and glideslope transmitters [4]. The most recent classification method utilised since 2017 is shown in figure 1.

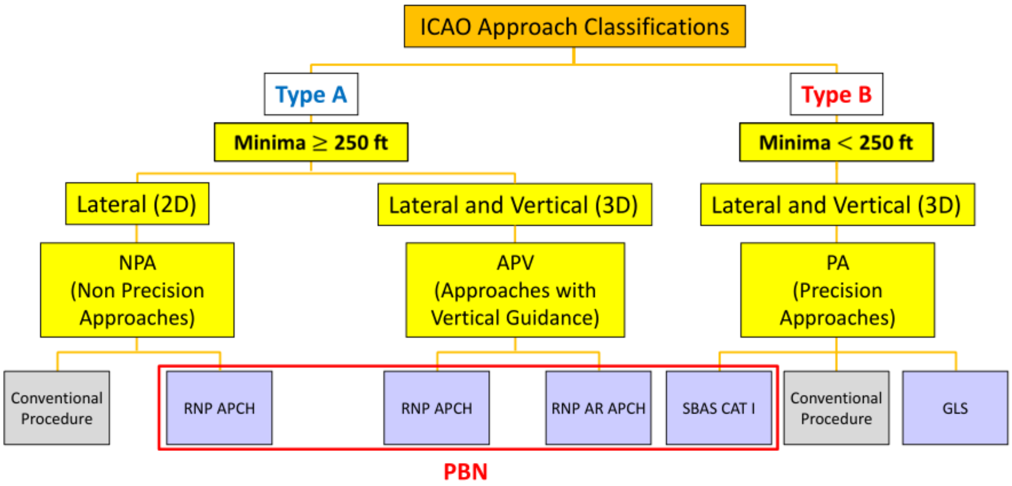

Fig. 1. ICAO approach classification model [5]

These systems, just like other precision-based ones, can be divided into different categories, as shown in table 1.

Table 1. Precision approach categories [6]

Category of Operation	Decision Height [ft]	Runway Visual Range [m]
CAT I	200	>550
CAT II	100-200	>300
CAT III A	0-100	>175
CAT III B	0-50	50-175
CAT III C	0	0

CAT III C takes place in no DH (Decision Height) and RVR (Runway Visual Range) conditions, meaning that an aircraft can approach and land under non-visual conditions. This reason, along with the difficulty of ground manoeuvring after landing, makes this category not operational and rarely used in most airports [6-7]. For this work, only precision-based approaches are going to be studied: the conventional procedure ILS and GLS (GBAS Landing System), both for CAT I operations.

3. CASE STUDY

The article leans over Viseu airfield, in Portugal. Just like many of the airfields in the country, Viseu airfield plays a very important role in the development of its region. It is located in the north-centre side of the country, 6,5km N to the city of Viseu. It takes part in a regional air transportation network (unique in the country) that connects the city of Bragança to Portimão every day and 6 days per week, performed by SevenAir. The airfield holds its own Aeroclub, as well as firefighting and health care services for its region. A training centre to produce commercial pilots, as well as cabin assistants and maintenance technicians have also just got installed. For these and many other reasons, it is considered one of the most important airport infrastructures in the country, right after the international airports of Oporto, Lisbon, and Faro. An example of its verified growth can be observed in figure 2.

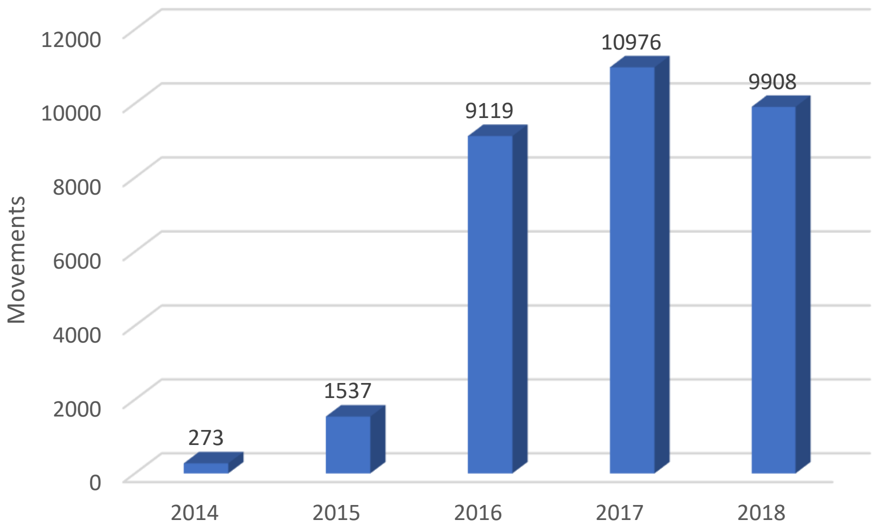

Fig. 2. Viseu airfield traffic evolution (movements) over the past years [8]

The movements increase since 2014 is huge. From 2016, they have stabilized with the only decrease being verified in 2018, which is explained by the really bad weather conditions in that year, preventing a lot of aircraft from landing in safety. In 2019, the predictions are for movements to increase significantly again, surpassing the values of the previous years. A survey delivered to local companies also showed that the majority agreed on the importance that the airfield has and could have for them and for the region, at the business level. In the following subsections, a prediction for the airfield movements in future years was performed, by using different forecast models.

3.1. Forecast methods

To predict the airfield movements' evolution for the next 10 years, two forecast methods were used. The first one was analysing the companies' evolution over the years (in Viseu) and relate them to the movements registered in the airfield.

The second method was reviewing IATA (International Air Transport Association) forecasts and applying its percentage growth to the airfield. For both methods, only the movements from the years 2016, 2017 and 2018 were analysed, taking into consideration the huge discrepancy with the previous two years where the air traffic in the aerodrome was very scarce. Each of these methods is shown next.

- Multiple linear regression model (firms)

In table 2, the variable (firms) and its corresponding movements are represented.

Table 2. Firms and Movements in Viseu (2016-2018) [9]

Year	Firms	Movements
2016	27276	9219
2017	27670	10976
2018	28064	9908

From this table, and by forecasting the movements in the function of the number of firms (from 2019 to 2029), figure 3 was obtained.

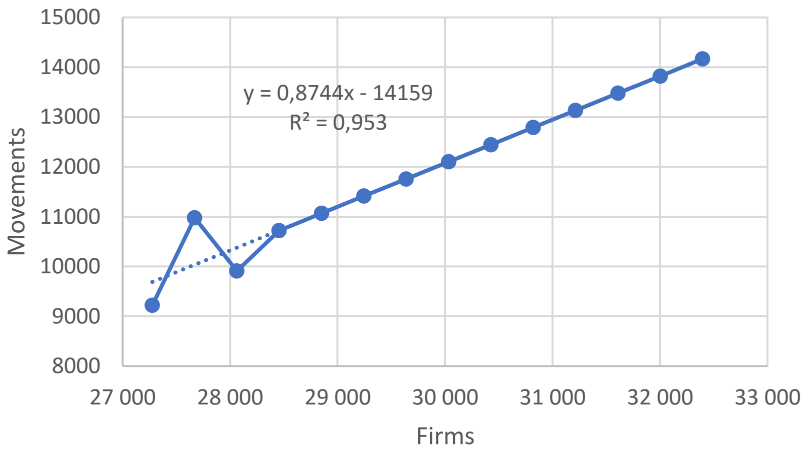

Fig. 3. Movements forecast (multiple linear regression model – firms), [own elaboration]

By performing a variable change and substituting the number of firms for the corresponding year, the number of movements can now be calculated by using the respective year in the equation, as seen in figure 4. The graphics are similar and the R^2 remains the same.

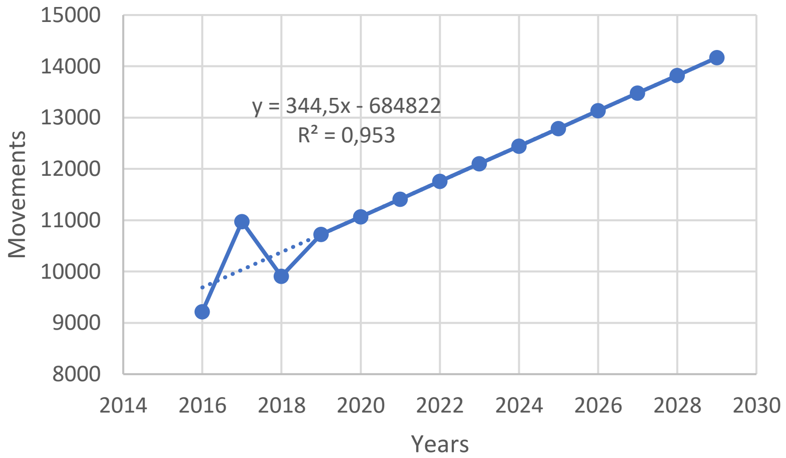

Fig. 4. Movements forecast, [own elaboration]

The R^2 (coefficient of determination) can vary from 0 to 1 and it is a statistical measure of how close the data are to the fitted regression line. The R^2 obtained of 0,953 means that the model can explain 95,3% of the real outcome.

- IATA forecast

An increase of 3.9% (2014-2024) and 3.4% (2024-2034) in the airfield movements was predicted by IATA. Using these forecasts, figure 5 was obtained.

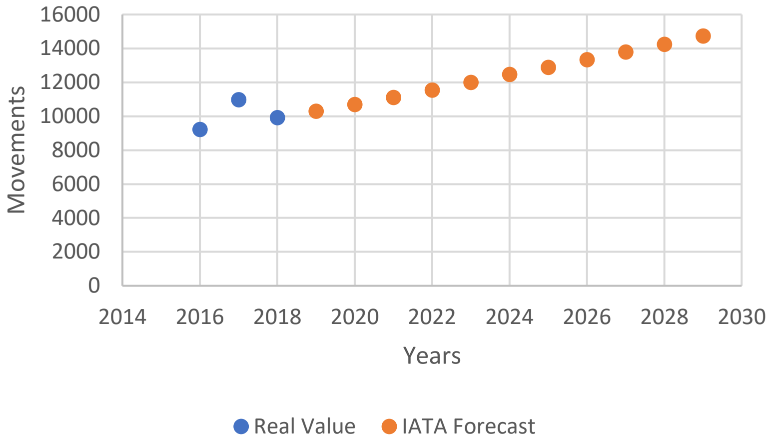

Fig. 5. Movements forecast – IATA, [own elaboration]

It can be easily observed that in both cases, the number of movements is expected to increase, following a linear function. Both models produce very similar results. Since IATA forecasts are a little less conservative, and because the airfield movements for 2019 are already expected to hit high values, IATA forecasts were chosen as the preferential model to be used for the rest of this study.

4. ILS VS GBAS

4.1. Technical analysis

The first system considered was an ILS. The needed equipment consists of a localizer (for lateral guidance) and a glideslope (for vertical guidance). An ILS receiver in the aircraft is also essential. Knowing that one ILS installation for each of the two runways in the airfield wouldn't be efficient, the preferential choice is runway 36, because there aren't any obstacles near.

The second system analysed was a GBAS. The equipment needed for this system consists of 2 to 4 GNSS (Global Navigation Satellite System) reference receivers and their respective geographically separated antennas; a VHF (Very High Frequency) data broadcast transmitter, a monitor system, approach database, and ground processing functions. For the inboard equipment, the essential elements are an Aircraft GNSS receiver function, a VHF data broadcast receiver function, and an aircraft navigation processing function. For each of these systems, the equipment needed is not existent on the airfield and needs to be acquired.

It is also important to note that the introduction of GNSS-based operations will allow the decommissioning of some traditional navigation aids, as seen in figure 6.

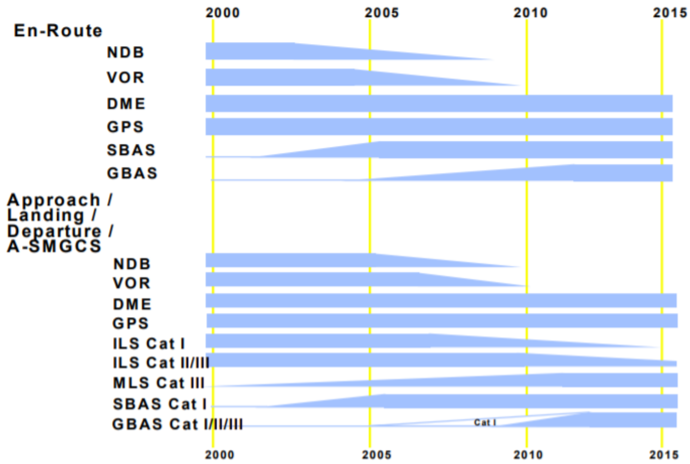

Fig. 6. ECAC navigation strategy roadmap [10]

From a technical point of view, the go-to system would be the GLS [11]:

- One simple station of this system has enough coverage for all the runways at the installed airport, unlike the ILS where it can only cover one runway end;
- The number of users per approach is unlimited, as opposed to ILS where only one single user is allowed;
- 26 approaches from 1 ground, as opposed to 1 from ILS;
- More flexible approaches: multiple glide slopes: thresholds, offsets, and no ILS critical area reducing flying time and fuel consumption.

The main disadvantage of this equipment is its full dependence on GPS, where some unwanted interferences in the signal could end up disabling the whole system, and possibly an airport and its runways. From a pilot perspective, flying a GLS is basically the same as flying an ILS. The procedure, displays, and the warnings are all the same, keeping GLS training to a minimum.

4.2. Economic analysis

In this case, the economic study was based on analysing the past and the current number of movements in the aerodrome and to estimate its corresponding taxes for the following years. Considering that 60% of all the movements in the airfield were paying the fixed tax values, presented in table 3, it was determined an average cost of 7,93€ per movement. Parking, night movements, and luggage taxes weren't considered, given their very low amount.

Table 3. Airfield charged fees, [own elaboration]

Type	Taxes	
Day/ton	12,38€	
Night/ton	18,46€	
Parking (>2hours)	Inside Platform	Outside Platform
	11,73€	6,52€
For services offered (luggage)	0,87€	

After the installation, the taxes were estimated to increase by 15%. Thus, figure 7 was obtained.

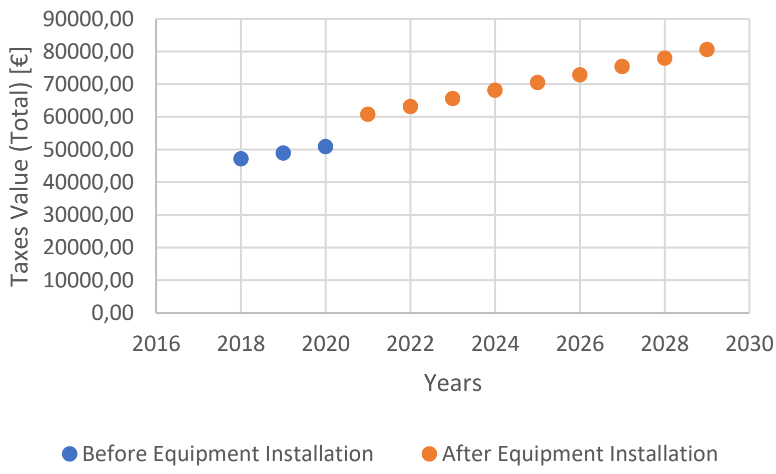

Fig. 7. Viseu airfield taxes forecast, [own elaboration]

By summing up the values obtained after the installation from 2021 to 2029, a total value of 635 245,67€ from the taxes was estimated, as depicted in table 4.

Table 4. Total taxes value after equipment installation, [own elaboration]

Year	Total Movements	Paying Movements (60%)	Taxes [€]	Total (cumulative) [€]
2021	11113	6668	60 807,19	60 807,19
2022	11546	6928	63 178,67	123 985,86
2023	11997	7198	65 642,64	189 628,50
2024	12465	7479	68 202,70	257 831,2
2025	12888	7733	70 521,59	328 352,79
2026	13327	7996	72 919,32	401 272,11
2027	13780	8268	75 398,58	476 670,69
2028	14248	8549	77 962,13	554 632,82
2029	14733	8840	80 612,85	635 245,67

After estimating the total income from the charged fees in the airfield, ILS and GBAS equipment costs were analysed, as shown in table 5.

Table 5. ILS and GBAS associated costs [10-14]

ILS CAT I installation costs	Price [€]	GBAS Cat I Installation costs	Price [€]
DME and ILS CAT I infrastructure	1 500 000	Infrastructure	500 000
Installation and commissioning		Civil works	44 000
Civil works	195 000	Installation and commissioning	120 000
Calibration	30 000	Initial flight certification	30 000
CAT I operation costs (per year)	79 000	Operating cost (per year)	43 000

By comparing both values, it is easily noticed that a GLS implementation is a lot cheaper than an ILS one, saving up to 1 391 000€ over a 10-year time. It was also previously seen that technically, GBAS offers more solutions in comparison to an ILS. Knowing this, and that a European investment project can fund 80% of the costs, table 6 was constructed.

Table 6. Breakeven point (with 80% fund), [own elaboration]

GBAS CAT I	2021	2022	2023	2024	2025	2026
Equipment cost [€]	694 000	-	-	-	-	-
Equipment cost with 80% fund [€]	138 800	-	-	-	-	-
Operation costs [€]	43 000	43 000	43 000	43 000	43 000	43 000
Revenue [€]	60 807,19	63 178,67	65 642,64	68 202,70	70 521,59	72 919,32
Balance [€]	-120 992,81	-100 814,10	-78 171,51	-52 968,81	-25 447,218	+4472,11

The revenue is directly related to the total capital obtained from the charged fees in the airfield, every year. When the balance reaches a positive value, that's when the equipment is fully paid, and the airfield begins profiting from its installation.

5. CONCLUSIONS

The article analyses the possibility of the implementation of a new precision-based approach system in Viseu airfield, in Portugal. The two systems analysed for this case were ILS and GBAS. As can be seen from the studies, a GBAS landing system would bring the most advantages in comparison to traditional ILS.

From a technical point of view, not only it is simpler to install but also more practical, since one single GBAS station can support multiple runways ends, reducing the number of systems at the airfield. The airfield is already using GNSS procedures to approach and landing, a GBAS installation would highly increase the precision obtained in these flight phases, especially in bad weather conditions. It can also be easily upgraded to a CAT II/III system, which may be required and very useful for the airfield in future times. In economic terms, a GBAS installation also ends up as the better option in comparison with ILS, with lower equipment and operating costs. Not only this but also possible modifications to permit CAT II/III operations wouldn't result in an increase in the operating costs in the GBAS facility, as opposed to ILS.

Knowing that a European investment project can fund around 80% of the investment and estimating the revenue from the airfield taxes after the equipment implementation, it was determined a six-year investment recovery forecast for the airfield, from the installation of a GBAS system.

Approach and landing systems will increasingly move to GNSS based landing to improve airport accessibility either in CAT I conditions or CAT II/III conditions. Overall, a GBAS landing system looks like the better option for a precision-based system in these phases of flight, offering better solutions at a lower cost compared to the other alternatives.

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